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A. H. G. ALSTON, B.A. (Oxon)
Systematic Botanist, Department of Agriculture, Ceylon

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Macrophomina Phaseoli (Maubl.) Ashby

AND

Rhizoctonia bataticola (Taub.) Butler

BY

J. C. Haigh, B.Sc., A.R.C.S., A.I.C.T.A.

Assistant Mycologist, Department of Agriculture, Ceylon

WITH SEVEN PLATES

In the *Transactions of the British Mycological Society* for 1927 Ashby (10) established *Macrophomina Phaseoli* (Maubl.) Ashby as the pycnidial stage of *Rhizoctonia bataticola* (Taub.) Butler. The determination was made on the examination of pycnidia and spores from jute, sesame, pigeon pea and beans and of the sclerotial forms produced when the pycnospores were grown on culture media. On two occasions, one recorded in February, 1928, (13) and the other in the present paper, pycnidia of *Macrophomina Phaseoli* have been obtained in culture ; otherwise they have been found only in nature, and in the absence of evidence to the contrary it has been assumed that all sclerotial forms referable to *Rhizoctonia bataticola* will have as their perfect stage the pycnidial form *Macrophomina Phaseoli*. These sclerotial forms " range from 50 to 150μ in diameter in the tissue of herbaceous plants, but in the roots of woody plants Small found them up to 0·8 by 1·0 mm. in size ; in cultures the variation is from 50 to 200μ " (10). In Ceylon the sclerotia have been found on more than fifty plants, but the hosts of the pycnidia are two only, beans and sunflower. The Ceylon sclerotia have exhibited the wide range in size quoted above, but have exhibited it in culture as well as in nature. It will be shown that these sclerotial forms are divisible by mean sclerotial diameter into three groups which are stable and distinct one from another. As far as is known at present, pycnospores of *Macrophomina Phaseoli*, from whatever source they were isolated, have always given in culture sclerotia which belong to the lowest of these groups, which accounts for the remark of Ashby quoted above, " in

cultures the variation is from 50 to 200μ." The statement was no doubt based on the examination of the sclerotia produced by germination of spores from the various pycnidial forms now gathered together under the new binomial *Macrophomina Phaseoli*. In view of the grouping to be established in the present paper, it is by no means certain that all sclerotial forms now included in *Rhizoctonia bataticola* will have *Macrophomina Phaseoli* as their perfect stage, and in view of this possibility it is intended in this paper to refer to the sclerotial forms as *Rhizoctonia bataticola* and to reserve the name *Macrophomina Phaseoli* for the pycnidial stage.

It has been found in the course of work on the morphology of the sclerotium of *Macrophomina Phaseoli* (Maubl.) Ashby (= *Rhizoctonia bataticola* (Taub.) Butl.) that the strains of the fungus isolated from different hosts may be separated into three groups, the division being based on mean sclerotial diameter in culture. The first group, which has been known throughout the course of the present work as the C group, contains those strains with a mean sclerotial diameter of 120μ or less; strains of the middle or B group have a mean sclerotial diameter round about 200μ, while the A group contains those strains whose sclerotia are commonly measured in millimetres and tenths of a millimetre. Arbitrary as this grouping undoubtedly is, it has nevertheless been found to be entirely reliable during a period in which hundreds of cultures have been examined. It must be understood that the basis of classification is the *mean* sclerotial diameter; the upper limit of the range of sclerotial diameter in the C forms distinctly overlaps the lower end of the range of the B group, but the means remain distinct. The distinction is such that with very little practice cultures of A, B and C forms can be distinguished with the naked eye (plate XXV, figs. 1–3). It will be shewn in the course of these notes that they may further be distinguished in other ways, although the differences are not considered sufficient to warrant separation into different species at present. Previous workers have described the fungus as it occurs in nature and have not found either in structure or in mode of development any necessity for division into groups; in fact Small (9) says, after having described sclerotia varying in size from 0·06 mm. (group C) to 0·7 mm. (group A), "There was considerable variation in both size and shape of the sclerotia of *Sclerotium bataticola* from the different hosts, but all were alike in colour, in structure and in oily content. The smaller sclerotia of herbaceous plants were paralleled by those of woody hosts like *Eucalyptus*, and the internal hyphae of all the hosts were strongly alike, especially in the woody plants." The description of the development of a sclerotium of the A group by Small (5) in one of his earlier papers is almost identical

with that given by Briton-Jones (8) in describing the formation of sclerotia measuring from 50–85μ and therefore falling into group C. It may therefore be asked why there should be need for separation, since in mode of development and in structure the sclerotia of the various groups are identical. The reasons are to a certain extent hypothetical, and are :—

(1) *Rhizoctonia* is a form genus, and, like other form genera, may contain species differentiated only by size of parts.

(2) The strains so far examined are perfectly stable in so far as mean size of sclerotium is concerned.

(3) The pycnidial stage, *Macrophomina Phaseoli*, has so far as is known been connected only with sclerotia of the C group. It is the writer's conviction that *Macrophomina Phaseoli* will always give in culture sclerotia of this group ; in the event of which it may be necessary to remove the A and B forms to another species. Small (5) noted clamp connections and a supposed hymenophore in a strain from *Grevillea* whose sclerotial size would place it in the A group ; this would suggest the perfect stage, if any, of the A strains to be a Basidiomycete.

(4) There is a possible connection between sclerotia of the A group and the black lines found in woody tissues by Small and attributed by him to *Rhizoctonia bataticola*. The morphology of the A sclerotium and its connection, if any, with the black line is being studied by Small, and in the work about to be described only one A group strain has been included, and that merely for purposes of comparison.

It has been found that whereas from trees and woody plants generally may be isolated sclerotia belonging to any or all of the three groups (all three have been obtained at different times from rubber and from coconut), herbaceous plants in general yield only sclerotia of group C ; coincidentally, or possibly in consequence, pycnidia of *Macrophomina Phaseoli* have been obtained only from herbaceous hosts.

The strains used in the present study, together with the abbreviations by which they will be known, are given below :—

Abbreviation.	*Group.*	*Host.*	*Country of origin.*
Ac. mel	A	*Acacia melanoxylon*	Kenya (J. Mc Donald)
Cocos	B	*Cocos nucifera*	Ceylon (M. Park)
Cacao	B	*Theobroma cacao*	,, (W. Small)
P_4	B	*Hevea brasiliensis*	,, ,,
H_{14}	B	,, ,,	,, ,,
Hib	B	*Hibiscus Rosa-sinensis*	,, ,,
T_{97}	B	*Thea sinensis*	,, ,,
Tea	B	,, ,,	,, ,,
Clit	B	*Clitoria cajanifolia*	,, ,,
Boga	B	*Tephrosia candida*	,, ,,

Abbreviation.	*Group.*	*Host.*	*Country of origin.*
Sun	C	*Helianthus annuus*	Ceylon (J. C. Haigh)
M. Phas	C	*Phaseolus vulgaris*	U.S.A. (per S. F. Ashby)
Bean	C	,, ,,	Ceylon (J.C. Haigh)
Sw. P	C	*Ipomoea batatas*	U.S.A. (per S. F. Ashby)
Sw. P.C	C	,, ,,	Ceylon (W. Small)
G.G	C	*Panicum maximum*	,, ,,
Ses	C	*Sesamum indicum*	,, ,,
Alb	C	*Albizzia lopantha*	,, ,,
Jun	C	*Juniperus* sp.	,, ,,
TcR	C	*Thea sinensis*	,, (L. S. Bertus)
Cit	C	*Citrus medica* var. *acida*	,, (W. Small)
Straits	C	*Hevea brasiliensis*	Federated Malay States (J. Weir)
Tob	C	*Nicotiana tabacum*	Ceylon (W. Small)
Caj	C	*Cajanus indicus*	,, ,,
Musa	C	*Musa paradisiaca*	,, ,,
Rhod	C	*Eucalyptus rostrata*	Rhodesia (J. C. Hopkins)
Ac	C	*Acacia decurrens*	Ceylon (W. Small)

It will be noticed that the hosts of these strains include Dicotyledons and Monocotyledons, Angiosperms and Gymnosperms. The strains labelled Bean, M. Phas and Sun were isolated from pycnidia on the host, the rest from sclerotia or root fragments.

THE C STRAINS

In the C strains growth is rapid and sclerotia become visible in two or three days, although microscopic examination of young cultures shews that they begin to be developed at once. A culture one day old and 0·4 inches in diameter shewed all stages from the very young

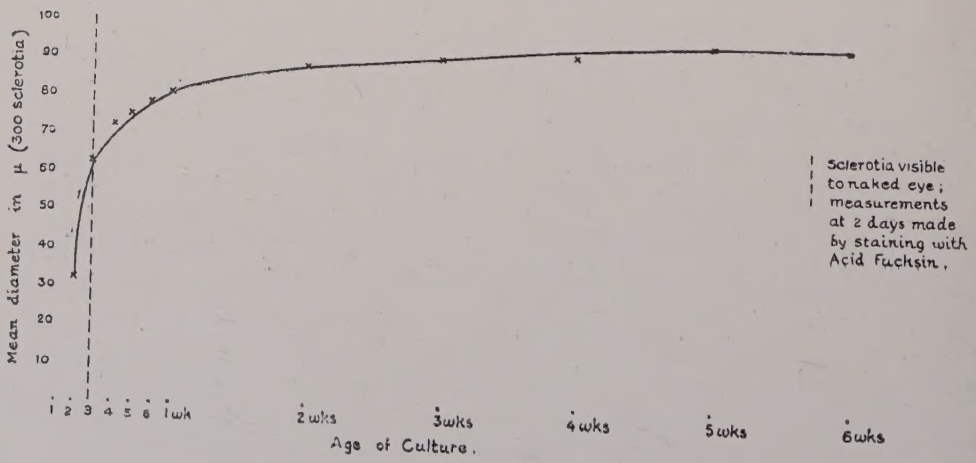

Fig. 1

to the half developed, as can be seen from plate XXVIII, figures 4-6. In a normal culture the sclerotia are evenly distributed throughout the

medium and quickly become black and carbonaceous. Under the microscope they become opaque in about one week and measurements taken at frequent intervals over a period of five months indicate that they attain their maximum size (and therefore presumably maturity) in four to six weeks. Text fig. 1 shews successive mean diameters of 300 sclerotia measured at short intervals, and gives a rough idea of the rate of development. Each point on the curve represents the mean of six measurements (each of 50 sclerotia) from six cultures of the same age. There is no doubt that a similar curve, based on the measurements of a single sclerotium, would be considerably steeper in trend. The successive measurements which go to make the curve are taken at points equidistant from the centre of the culture so as to be comparable, but the average is reduced by the new sclerotia which are continually being formed. For this reason the measurements recorded in table I were not made until the curve had become horizontal in trend, *i.e.*, until the culture was four weeks old. In old cultures the sclerotia tend to occur in aggregates which are, however, comparatively easy to distinguish (cf. Shaw (6)). This is found particularly in slant cultures. The uniform conditions of food and moisture in a culture medium and the absence of resistance to growth such as is found in plant tissues result in the production of sclerotia of much more regular shape than those found in nature and the majority of sclerotia approximate to a spherical form. Large bodies of markedly irregular shape are therefore viewed with suspicion. These aggregates have not been observed in A or B strains.

Aerial mycelium is always present in greater or less degree varying with the strain and the medium ; all strains produce a greater mycelial growth on potato dextrose agar than on prune or maize meal agar (cf. Briton-Jones (8)). There are several characteristics such as amount of aerial mycelium, colour of young mycelium and behaviour on plain agar which serve to distinguish strains one from another and which have tended to be regarded as diagnostic. It must be realised, however, that the all-important test is the connection with the pycnidial form, *Macrophomina Phaseoli*, and where two forms are found both to have the same pycnidial stage the differences noted above must be regarded as of minor importance. At the present stage of this work five only of the numerous strains examined have been actually connected with the pycnidial stage ; it may therefore be useful in the meantime to set forth the variations which have appeared regularly.

Minor differences due to the medium employed are found in all fungal cultures, an observation which applies with particular force to dimensions of reproductive organs ; it should therefore be stated at

the outset that unless otherwise indicated all cultures are grown at laboratory temperature (approximately 26° C) on maize meal agar prepared according to the formula maize meal 100 gm., agar agar 20 gm., water (distilled) 1,000 cc.

The main characteristics of the strains examined are set out in table I below.

Column 4 indicates the range of *mean* sclerotial diameter. Measurements were made in batches of fifty and the × shows the position of the mean sclerotial diameter for two hundred sclerotia. Measurements were made in all cases with a micrometer eyepiece and the calculated mean is correct to 4μ. Individual measurements were subject to an error of ± 4μ and the mean is correct within the same limits.

Column 3 headed "Chromogenesis" notes slight colour differences exhibited by different strains and appearing regularly. These had been noticed from time to time in the stock cultures grown on maize meal agar, and attention was redrawn to them by observations made by Ashby when examining cultures of *Rhizoctonia bataticola* at the Imperial Bureau of Mycology.

Column 2 shows the behaviour of strains on plain agar. It is found that whereas strains of the A and B groups behave normally when grown on plain agar, some strains of the C group fail to produce sclerotia on this medium. The purity of the cultures can be tested by reinoculating on to maize meal agar, when the normal growth is reproduced.

Failure to produce sclerotia has also been exhibited on maize meal agar and on (Difco) potato dextrose agar from time to time and must be regarded as a form of saltation. Sterile forms have been produced at various times by the strains from *Acacia*, *Albizzia*, *Citrus* and *Musa*, and several other strains have shown an intermediate form in which sclerotia are scattered in groups through the culture or are formed only on the glass of the tube away from the culture medium. Such intermediate forms and two cases in which the normal form was reproduced from the abnormal by changing the culture medium are held to furnish conclusive evidence in favour of saltation. Without such evidence it would be difficult to reach a definite decision, for though the mycelium remains essentially unaltered such mycelium is not exclusive to the genus *Rhizoctonia*, and in the absence of sclerotia there is missing the definite character which distinguishes *Rhizoctonia* from the rest of the *Mycelia Sterilia*.

Saltations such as are mentioned above may arise spontaneously or as a result of change of environment. The first observed saltation (in the strain from *Albizzia*) occurred in cultures which were being used to enquire into the cause of zoning. It was observed that some strains

Table I

Characteristics of C strains of Rhizoctonia bataticola

	Chromogenesis.			*Range of mean sclerotial size in μ.*
Strain.	*On plain agar.*	*On maize meal.*	*On Dox.*[1]	*52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112 116*
Alb	No sclerotia	Mycelium brown	Pink coloration	
Straits	Sclerotia	Young mycelium green	No coloration	
Rhod	Sclerotia	,, ,, white	No coloration	
Caj	Sclerotia	,, ,, green	Wine-red coloration	
TcR	Sclerotia	,, ,, white	Pink coloration	
Sw. P	No sclerotia	,, ,, ,,	No coloration	
Tob	No sclerotia	,, ,, ,,	Pink coloration	
Cit	No sclerotia	,, ,, ,,	Pink coloration	
Jun	No sclerotia	,, ,, ,,	No coloration	
Bean	Sclerotia	,, ,, ,,	Wine-red coloration	
M.Phas	Sclerotia	,, ,, ,,	No coloration	
Musa	Sclerotia	,, ,, ,,	No coloration	
Sun	Sclerotia	,, ,, ,,	No coloration	
Sw. P.C	Sclerotia	,, ,, ,,	No coloration	
G.G	2	Mycelium green	No coloration	Sterile

1 A modified Dox's agar consisting of KNO_3 2·0 gm ; MgSO4 (cryst.) 0. 5 gm ; K_2HPO4 1. 0 gm ; Cane sugar 15·0 gm ; $FeCl_3$ 1 drop ; Agar 15·0 gm ; Water (dist.) 1000 cc.

2 Forms, not sclerotia, but cell-shapes identical with those produced in prune agar (see p. 221 and plate XXIX).

shewed a faint but definite concentric zoning in plate culture, particularly when grown on (Difco) prune agar (cf. plate XXV, figures 1 and 4). In the course of experiments with such strains there occurred two independent saltations, one involving the whole plate and a second in which one-quarter of the plate developed a brown sterile mycelium, while the rest of the plate was normal (plate XXVI, figures 1 and 2). Subcultures from both normal and abnormal forms were made on different media and on media of varying depth. In the majority of cases the sterile form remained so and further cases of saltation from normal to abnormal form were encountered, but in two cases the normal form was reproduced from the sterile form by changing the culture medium. On maize meal agar the sterile saltant produced a regular growth of brown hyphae and the form of the culture differed from that of the normal only in that sclerotia were lacking. On prune agar a characteristic dendroid growth was obtained (plate XXVI, figure 3). This growth increased in diameter very slowly and subcultures have been observed for twenty days without any appreciable increase in size beyond the production of aerial mycelium. There were no sclerotia, merely a branching mycelium of dark-brown tuberous cells. The actual form of the growth varied with the depth of the culture medium. On thin media the growth was branching and root-like; on thick media the growth was compact, quite solid below the surface and attempting to produce the dendroid structure on the surface. In both cases, however, the actual mycelium was the same.

One strain isolated from guinea grass (*Panicum maximum*) has been abnormal from the initial isolations from the dead roots of the host. The growth is compact and increase in size is slower than usual; the aerial mycelium is grey-white while that in the medium is dark in colour. The first isolations gave a few sclerotia scattered among the stroma-like mycelial mat, and occasional subcultures gave chlamydospores only. These chlamydospores were identical with those figured by Small (5) and when cultured reproduced the original green mycelium and scattered sclerotia. For the past year, however, this strain has been completely sterile in maize meal cultures; aggregations of hyphae somewhat resembling sclerotia macroscopically have been produced, but examination shews them to be devoid of structure. Inoculation on to rubber twigs resulted in a copious production of normal sclerotia over the surface of the twig, the sclerotia being typically of the C form, but reisolation to maize meal agar gave only sterile mycelium identical with that used for the original inoculation.

It has been possible to find a graded series from the normal to the completely sterile form. Among a collection of stock cultures were found

at one and the same time many normal growths and three apparently sterile ones. On closer examination these three were found to be distinct one from another and to form a series. The first, a subculture of the tobacco strain, had the dark brown mycelium, slightly thinner than the normal, which is associated with the sterile saltant, with a few sclerotia scattered among the hyphae. The sclerotia were normal. The normal form of this strain was recovered by transferring to plain agar and subsequently back to maize meal agar. The second member of the series was an isolation from *Sesamum* and had the thin brown hyphae intermingled with abortive sclerotia—collections of rounded cells, colourless, such as might be expected in the very early stages of sclerotium formation on young hyphae. These bodies were quite distinct from the chlamydospores or abnormal cell-shapes recorded by Small (5). They were hyaline and thin-walled and had protoplasmic contents, whereas the cell-shapes of Small are brown and full of oil drops. They were never seen to develop into the normal sclerotium. The third member of the series, a saltant from an *Albizzia* isolation, was completely sterile.

The four forms described above, while not differing markedly in appearance when grown on maize meal agar, were easily distinguishable in plate culture on (Difco) prune agar, and must be held to be independent variations in different directions. The guinea grass strain came nearest to a normal growth on this medium. It produced a dense radial growth of dark green hyphae with collections of cells which approached very nearly to the normal sclerotium, but differed in several respects. They did not attain the regular shape characteristic of the normal sclerotium and their structure was discernible even in age. They were slower and less even in development, as can be seen from the many different stages to be found in the same sample (plate XXIX). The younger stages strongly resembled chlamydospores and but for their future development might be determined as such, but they differed from the chlamydospores recorded by Small (5). They did not appear to be thick-walled, and in the early stages at least seemed to have protoplasmic contents. Their pigmentation was intense, being green in the young stage and darkening with age so as to become black and so dense as to seem to diffuse pigment into the surrounding medium. The larger bodies represented in plate XXIX had all to be cleared in chlorate of potash and concentrated nitric acid before they could be drawn. It was then seen that each cell contained one large oil drop which almost filled the cell cavity. The cell walls appeared still to be thin. The final stage was a body about the size of a sclerotium but irregular in outline and homogeneous in structure. On plate XXIX will be noticed a thick-walled body which would agree with the normal chlamydospore,

but these bodies were very rare. Structures similar to those figured on plate XXIX have been observed independently by Small.

The *Sesamum* strain on the same medium gave a dark green regular growth of radiating hyphae in which the cell-shapes characteristic of *Rhizoctonia bataticola* were prominent. The tobacco strain gave a white, sterile mycelium, while the *Albizzia* strain reproduced the dendroid growth described on page 220 and figured in plate XXVI, fig. 3.

The most interesting of all the saltations observed took place in the strain isolated from *Cajanus indicus* when that culture was grown on sterilised *Cajanus* twigs in Roux tubes. The change was not to a condition of sterility, but in the opposite direction, and resulted in the production of a strain giving pycnidia of *Macrophomina Phaseoli* in culture, either with or without sclerotia. A detailed account of this phenomenon is given later in the section on " Growth in Plant Tissues."

ZONING

It was noted above that several of the C strains showed faint concentric zoning in plate culture, particularly when grown on (Difco) prune agar (plate XXV, figure 4). The zones were regions of varying concentration of sclerotia, and attempts were made to find the cause or causes of such variation. Lack of adequate facilities made the results of those experiments inconclusive, but it may be of interest to give here a brief account of what has been done.

(1) Three plate cultures were grown in the dark, but exposed to sunlight for two separate periods of one and a half hours each. Three cultures were grown under normal conditions and three were grown entirely in the dark as controls. At each exposure of the first three plates a pencil mark was made on the glass at the outside edge of the colony. It was found that a distinct zone, the edge of which corresponded exactly with the pencil mark, was produced as a result of each exposure. Immediately outside the pencil mark was a region in which the concentration of sclerotia was decreased, recovering quickly when the cultures were replaced in the dark. The controls each showed a faint zoning, there being no appreciable difference between those left on the laboratory bench and those kept in the dark.

(2) Three plates were grown in the dark and at laboratory temperature except for one exposure of five hours to a temperature of 38·5°C. Controls were as before. The growth at the higher

temperature was well-marked and consisted of a band, 2 mm. in width, of increased sclerotial production. The controls gave the same results as before.

(3) Three plates were grown in the dark and at laboratory temperature except for exposure to the heat of the sun's rays for varying periods. The cultures were wrapped in black paper throughout the experiment so as to obtain the result of exposure to the heat of sunlight without the complication of the light factor. Controls were as before. An exposure of three hours resulted in a temporary check to growth which took twenty-four hours to overcome. Then followed a narrow zone of much decreased sclerotial concentration, followed by a growth more dense but not so dense as that before the plates were exposed. An exposure of six hours was sufficient to kill the cultures. The controls gave the same results as before.

The formation of sclerotia is regarded as a vegetative process, since such results are obtained when the condition of higher temperature is imposed before the sclerotia are formed. The variation in temperature in the laboratory at the time of the experiments was less than two degrees in the twenty-four hours, so that the zoning produced in the cultures grown entirely in the dark was presumably not due to diurnal temperature variation. Since there was no appreciable difference in zoning between those cultures grown in the dark and those grown under normal laboratory conditions the zoning in the latter could not be attributed to the alternation of light and darkness by day and night. A temperature of 38·5°C acted as a stimulant and was probably nearer to the optimum temperature for the fungus than that of the laboratory (26°C.) The temperature of sunlight acted as an inhibiting factor, even for short periods, and was presumably above the optimum for the fungus. An attempt to determine the temperature range of the fungus failed for lack of the necessary apparatus, and an attempt to subject the fungus to the action of continuous light without heat was unsuccessful for the same reason.

THE B STRAINS

In strains of the B or intermediate group growth is slower than in the smaller forms. The mycelium is usually green and the intensity of colour may be such as to obscure the sclerotia in the early stages. The green colour develops about the fourth or fifth day when the sclerotia are beginning to be visible; the youngest mycelium is always white. Sclerotia first appear at about the same age as in the C forms (Text fig. 2),

but their development is more gradual. Even when they appear opaque and well-formed microscopic examination shews them to be indefinite and the hyphae composing them can be seen. They never become so clearly cut as those of the A and C groups, due chiefly to the persistence of the deeply-pigmented mycelium. There is little or no aerial mycelium in the B forms, and the surface of an old culture is invariably smooth and

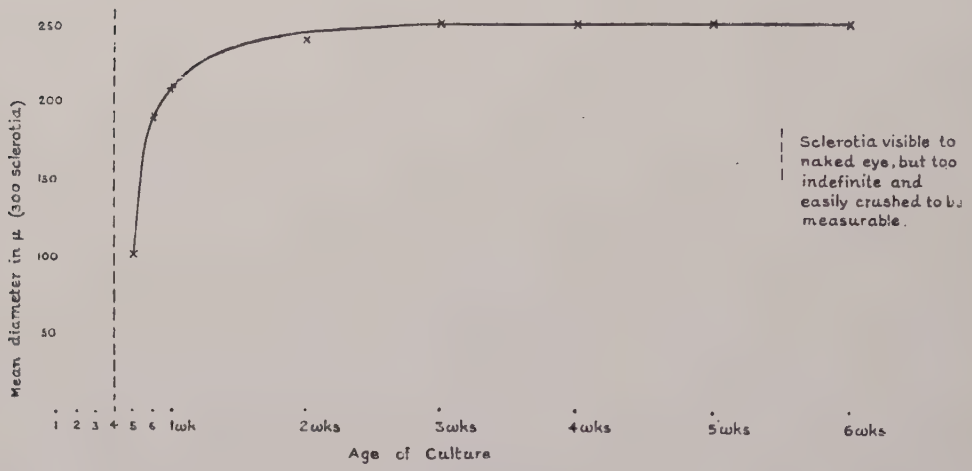
Mean diameter in μ (300 sclerotia)
250
200
150
100
50
1 2 3 4 5 6 1wk 2wks 3wks 4wks 5wks 6wks
Age of Culture
Sclerotia visible to naked eye, but too indefinite and easily crushed to be measurable.

Fig. 2

shiny, whereas it is unusual to find a C strain presenting such an appearance. The characteristic tuberous cells are developed to a much greater extent than in either of the other groups, but otherwise the mycelium differs from that of the C strains chiefly in intensity of pigmentation. It is found, however, that on other media, for example the Dox's agar previously mentioned, the mycelium of C strains shews corresponding pigmentation which causes the hyphae to become easily visible to the naked eye. The presence of sclerotia on the hyphae results in the beaded effect produced in cultures grown on this medium, as is well shown in the photograph on page 142 of Ashby's paper (10). The fine hyphae often found in A and C strains are not common in the B group.

Sclerotia of the B forms do not shew that tendency to form aggregates which is displayed by C strains. As a class strains of the B group shew more uniformity than the smaller forms both in sclerotial size and in behaviour. They are uniform in the production of sclerotia on plain agar and in the non-coloration of the Dox's agar mentioned above. They have not been observed to saltate in the manner shewn by C forms.

They are uniform in producing a green coloration (which varies in shade) of the surface of the culture medium in the region of the youngest hyphae. They appear to contain a greater quantity of oil than either the A or C groups.

On several occasions plate cultures of strains of the B group have shewn a tendency to variation manifested by unequal rates of growth in different parts of the culture, resulting in the production of a distinctly lobed outline (plate XXVI, figures 4 and 5). Similar observations have been made by Buddin and Wakefield (11) working with *Rhizoctonia crocorum* and the paragraphs here quoted from their work (p. 136) would probably apply with equal force to *Rhizoctonia bataticola* :—

" It is tempting to suppose that *Helicobasidium* is an extremely plastic organism from which mutants may readily arise. Some support for such a view is provided by the fact that in Petri-dish cultures, both of *Helicobasidium* and of *Rhizoctonia*, a curious sectoring effect is sometimes observed. Sectors of an otherwise pale-coloured colony may develop the deeper brownish colour ; or the hyphae of one sector may suddenly begin to grow much more rapidly than the rest of the colony, so that a markedly lobed outline is produced in place of the previous regular circular shape.

" If the explanation of the growth differences obtained is to be found in such a tendency to variation (or perhaps mutation) it is conceivable that the pathogenicity of the fungus is subject to similar variation. If that is so the non-success of many inoculations made with spore-cultures may be due to the fact that the majority of strains are but feebly if at all parasitic, whereas occasionally a more virulent form appears which will produce *Rhizoctonia* root-rot on a suitable host plant."

Attention will be redrawn to the second paragraph when the results of inoculations with *Rhizoctonia bataticola* are examined.

The mean sclerotial sizes of the B strains under examination are given in table II below.

Table II

Characteristics of B strains of Rhizoctonia bataticola

Strain.	*Chromogenesis.*			*Range of mean sclerotial size in μ.*					
	On plain agar.	*On maize meal.*	*On Dox.*	*150*	*175*	*200*	*225*	*250*	*275*
Boga	Forms sclerotia	Young mycelium brownish green	No coloration		—×—				
P_4	,, ,,	Young mycelium green	No coloration		—×—				
H_{14}	,, ,,	,, ,,	No coloration			—×—			
T_{97}	,, ,,	,, ,,	No coloration			—×—			
Tea	,, ,,	Young mycelium dark	No coloration			—×—			
Cocos	,, ,,		No coloration			—×—			
Clit	,, ,,	Young mycelium brownish green	No coloration			—×—			
Hib	,, ,,	,, ,,	No coloration				—×—		
Cacao	,, ,,		No coloration				—×—		

THE A STRAINS

Although one A strain only has been studied it is believed that the group is a very uniform one, and that the few observations here set forth will apply to other strains of the same group.

The rate of growth in the A group is even more slow than in the B group, although sclerotia are developed at about the same age. The young mycelium shews the method of branching characteristic of the genus *Rhizoctonia*. In two days the older hyphae begin to shew a dark green pigmentation, and sclerotia develop among the darker hyphae. In four days sclerotia can be distinguished with the naked eye, but attempts to measure them meet with failure. They are as yet so immature that the pressure of the cover-glass is sufficient to crush them. In this immature state the outer layers of hyphae are so loosely woven as to make the sclerotium appear white by reflected light even when it is black by transmitted light. At the end of six days the sclerotia have sufficient definition to allow of measurement and from this point their development appears to be rapid. They become carbonaceous and brittle and exude oil when crushed. They are dark brown in colour and much more irregular in shape than either the B or C forms. The majority are not spherical, and measurements by the method used for the B and C groups cannot be made with the A forms. Sclerotia up to 2 mm. in length have been observed, and if one approximates by taking $\frac{1}{2}$ (length + breadth) as equal to diameter a mean size of 550μ has been obtained in cultures five weeks old. They present a distinctive appearance by virtue of a fringe of fine brown hyphae which persists round the sclerotium, giving the appearance of a halo. From the sclerotia there radiate other fine, aerial brown hyphae which are somewhat similar to the aerial hyphae of the C strains but which compare with nothing in the B group. The fine brown hyphae were first observed by Small, and will be dealt with in detail in a paper to be published by him. Except in the neighbourhood of sclerotia, vegetative mycelium is hard to find, and what little there is is of narrow diameter. The characteristic cell-shapes full of oil-drops which are so prominent in the B, and to a lesser extent in the C strains, are entirely absent from this group. The A forms produce no coloration when grown on modified Dox's agar.

No saltations of any kind have been observed in the strain under examination. " Pelotons " strongly resembling those of the mycorrhizal Rhizoctonias have been observed in a young culture of this strain, and are figured on plate XXX, figures 6 and 7.

DEVELOPMENT OF THE SCLEROTIUM

The earliest account of the development of the sclerotium of *Rhizoctonia bataticola* is that of Shaw (1) who described the fungus as it occurred on cotton and jute and erroneously named it *Rhizoctonia Solani*. His description is given below.

" In a hypha which is about to form a sclerotium, a large number of transverse divisions take place, so that a number of short barrel-shaped cells are formed which are very rich in oil globules. Some of these give rise to lateral outgrowths, consisting of one or two cells, which grow parallel with, and adhere to, the sides of the parent hypha. By the constant repetition of this process a mass of parenchymatous cells is formed which eventually becomes the mature sclerotium ; there is some slight differentiation into cortex and medulla, the central cells being large and thin-walled, while the peripheral cells have a smaller lumen and thicker walls."

This description is of sclerotia which fall into the C group of the present classification, but the account is so similar to that of Small (5) who described the structure and development of A forms that there can be little doubt that the process is essentially the same in the two groups. Further Small in a later paper (9) described sclerotia of the B group, and saw no reason to suggest that the process of sclerotium-formation in the forms there recorded differed in any way from the same process in the strains previously described.[1] The observations of the present writer lead to the same conclusion, that the development of the sclerotium is essentially the same in all forms. There is perhaps a tendency in the A and B forms for more than one hypha to take part in the process. Adjacent hyphae, much branched, have been observed frequently to become inextricably entangled in the early stages of sclerotium-formation, but the essential steps remain unaltered. There has been observed, however, in the C forms a process which results in the formation of a sclerotium and which differs from what may be called the normal process. The beginning of this process can be observed in a one-day-old culture of a C strain, where a young branch hypha as yet unseptate seems to swell at the tip. A similar process goes on in the secondary branches and the swollen young hyphae curl round one another so that a minute spherical body is produced. This takes place while the hyphae are young and full of protoplasm and before any but the first septations have occurred. Figures of the process are given on plate XXX, figures 1–5, and attempts to photograph the young structures are reproduced on plate XXVIII, figures 4–6. The subsequent history of these bodies is difficult to

1. It is now recognized by Small that his earlier paper (5) described A and B forms under the name *Rhizoctonia lamellifera*, and that the second paper (9), in which the identity of *Rh. lamellifera* and *Sclerotium bataticola* was recognized, dealt mostly with B and C forms.

follow, but as they eventually become sclerotia it is presumed that the sub-divisions mentioned in Shaw's account take place here also. The difference becomes therefore one of initial development and the final stages are presumably the same. The structures described above are easily seen by staining a one-day old culture of any C strain with acid Fuchsin (0·5 per cent. solution in lactic acid) and examining under the oil immersion lens. A two-day-old culture so treated shews sclerotial primordia of two kinds, one approximately spherical and produced as described above, and one more spindle-shaped, developed on the lines described by Shaw.

Some difficulty has been experienced in the study of sclerotial development. The method of Martin (3) did not give the desired success, and it was found that a cover slip placed on top of a young culture completely prevented the development of sclerotia in that area. The reason for this was not clear ; sclerotia developed in abundance inside the medium yet they would not develop on the surface under a cover glass. The observations recorded were eventually made by growing the fungus on slides on thin layers of culture medium. The slides were kept in sterile dishes and remained free from contamination.

PROTOPLASMIC ACTIVITY

Streaming of protoplasm was observed in one-day-old cultures of C strains and also in a three-day-old culture of an A strain. The movement was periodic and was observed to take place in either direction, *i.e.*, away from or towards the centre of the culture. The presence of septa appeared to be no bar to the flow, but as the cultures were very young it is possible that the septa were incomplete. It was not possible to connect the protoplasmic movement with the development of sclerotia or with any particular phase of activity.

STRUCTURE OF THE SCLEROTIUM

On plate XXV, figures 5–10, will be found microphotographs of sections of sclerotia of the A, B and C groups. It will be seen that in all cases there is differentiation into cortex and medulla. The cortex is thin, though in the smaller forms it appears thicker than in the larger. This is probably an optical effect due to curvature, which in a section of a small sphere will be considerably greater than in a section of the same thickness from a larger sphere.[2] From the section of the A sclerotium,

2. It can easily be shewn that in a section of a sphere between planes parallel to and equidistant from an equator, the depth of the meniscus at the edge of the section $= r - \sqrt{r^2 - t^2}$, where r = the radius of the sphere and $2t$ = the thickness of the section. Calling $\frac{r - \sqrt{r^2 - t^2}}{r} \left(= 1 - \sqrt{1 - \frac{t^2}{r^2}} \right)$ the "border effect" it can also be shewn that the border effect in a section 10 μ in thickness of a sclerotium 70 μ in diameter is one hundred times that in a section of the same thickness from a sclerotium 700 μ in diameter.

in which the curvature effect is least, it is seen that the cells of the cortex have a smaller lumen than those of the central portion of the sclerotium. There is in this section a suggestion that the cortex is composed of anastomosed hyphae rather than of a pseudoparenchymatous tissue like the medulla. The same structure is not distinguishable in the sections of the B and C forms, but Taubenhaus' (2) description of the fungus causing charcoal rot of sweet potatoes and falling into group C of the present classification states the sclerotium to have an "exterior smooth, made up of anastomosed black hyphae ; interior light to dark brown, made up of free, thick-walled, cortical, hyphal cells." The cells in the B form appear to be appreciably larger than those in the A and C groups, but this difference is insufficient in itself and it must be concluded that the sclerotia of the three groups are alike in structure.

GROWTH IN PLANT TISSUES

The object of the experiments about to be described was the production of the pycnidia of *Macrophomina Phaseoli*, and the establishment of a direct connection between the pycnidial form and the sclerotial forms described in the preceding notes. With one exception the attempts to produce pycnidia failed, but the results of the experiments may serve to indicate further the differences between the A, B and C groups of *Rhizoctonia bataticola* and between strains of the same group.

a. On stems of Cajanus indicus

The cultures were made on sterilised stems of *Cajanus indicus* in Roux tubes. The cultures were examined 18 days after inoculation and the results of the examination are recorded below.

Strain.	*Group.*	*Surface growth*	*Penetration.*	*Remarks*
Ac. mel	A	Good	Good	
Clit	B	,,	,,	
Hib	B	,,	,,	
H_{14}	B	,,	,,	
Boga	B	,,	Poor	Penetration good if bark removed.
Sw. P.C	C	,,	,,	,,
Tob	C	,,	,,	
TcR	C	,,	,,	Sclerotia in clusters.
Musa	C	,,	,,	
Jun	C	Fair	,,	
Alb	C	,,	,,	
Caj	C	Good	Good	Pycnidia produced ; see below.

It will be noted that in so far as penetration of *Cajanus* tissues goes the strains of the C group failed, with one notable exception ; on the other hand, the B strains and the one A strain under examination were successful. On plate XXVII, figures 1–5, are reproduced sections of the inoculated wood, and it will be further seen that there were degrees of failure among the C strains, that of the *Albizzia* strain being the most pronounced.

The exception to the general result obtained with strains of the C group was that of *Cajanus* which not only completely permeated the wood of the twig but also produced pycnidia on the surface. The pycnidia occurred among the dense mat of grey-green mycelium which covered the twig and which completely hid the abundant sclerotia on the surface of the wood (plate XXXI, figure 2). The pycnidia were sometimes scattered, sometimes botryosely arranged ; with a covering fringe of hyphae when young, but becoming clean and slightly shining with age. The occurrence of pycnidia was variable ; sometimes very few could be found, at other times the twig would be densely covered. A similar variation was noted in the occurrence of pycnospores ; where pycnidia were few, spores within the pycnidium were difficult to find. The pycnospores were typically those of *Macrophomina Phaseoli* (16–27μ × 5–11μ ; mean of 50=24 × 8μ) though pycnidia were found in which the spores were shorter and fatter than those usually associated with *Macrophomina Phaseoli*. The pycnospores were taken into culture on maize meal agar and produced a growth in which both pycnidia and sclerotia occurred (plate XXVII, figure 6). A full account of the isolations is given in the table below ; control twigs were used in all experiments, and remained clean. The cultures listed in the last column of the table are all stable forms.

No.	*Parent.*	*Medium.*	*Description of culture.*
1	Pycnospore from twig inoculated with *Cajanus* strain	Maize meal agar.	Pycnidia and sclerotia
2	Pycnospore from No. 1	,,	,,
3	Sclerotium from No. 1	,,	,,
4	Pycnospore from No. 3	,,	,,
5	Pycnospore from twig inoculated with *Cajanus* strain	,,	,,
6	do	,,	Sclerotia only
7	Sclerotium from twig	,,	,,
8	Pycnospore from twig inoculated with *Cajanus* strain	,,	Pycnidia and sclerotia
9	do	,,	,,
10	Pycnospore from No. 9	Plain agar	,,

No.	*Parent.*	*Medium.*	*Description of culture.*
11	Pycnospore from No. 10	Maize meal agar	Pycnidia and sclerotia
12	Sclerotium from No. 10	,,	,,
13	Sclerotium from twig inoculated with *Cajanus* strain	,,	Sclerotia only
14	Pycnospore from twig inoculated with No. 6	,,	,,
15	Pycnospore from twig inoculated with No. 7	,,	,,
16	Pycnospore from twig inoculated with No. 13	,,	Pycnidia only

The three cultures 14, 15 and 16 were put back on to *Cajanus* twigs. Nos. 14 and 15 produced the characteristic appearance described above, but No. 16 produced a distinctive growth with little mycelium (and that white) no sclerotia and abundant black pycnidia solitary, shining, with many spores (plate XXXI, figure 1 and cf. figure 2). These spores taken into culture gave pycnidia only, whereas pycnospores from the twigs inoculated with Nos. 14 and 15 produced a sclerotial form similar to that used for the original inoculations.

It is apparent that there has arisen by saltation a strain of *Macrophomina Phaseoli* which produces in culture pycnidia and sclerotia or either of these separately. This is the second occasion on which pycnidia of *Macrophomina Phaseoli* have occurred in culture, the first occurrence being that of a small group of pycnidia which arose spontaneously in a plate culture on maize meal agar and which was reported in *The Tropical Agriculturist* for February, 1928 (13). It is of interest to note that in that case, as in some of the present examples, there was a tendency for the pycnidia to be botryosely arranged. Further inoculations have been made, but at the time of writing the saltation has not occurred again. Saltations similar to that described above may, and probably do, take place in nature, and may play an important part in increasing the rate of distribution of the fungus. It is also conceivable that the young mycelium produced from a germinating spore may be a more effective weapon of attack than the mycelium arising from the germination of sclerotia.

b. On stems of tea and rubber

The inoculation experiments described above were repeated with tea and rubber twigs, but with less definite results.

The results are shown below.

Strain.	Group.	On stems of tea. Surface growth.	On stems of tea. Penetration.	On stems of rubber. Surface growth.	On stems of rubber. Penetration.
Ac. mel	A	—	—	++	+
Clit	B	—	+++	++	+++
Cacao	B	++	++	+++	+++
Boga	B			+++	+++
T97	B			+++	+++
Tea	B			+++	+++
Hib	B	—	++	++	++
H14	B	—	++	—	++
Cocos	B	+++	+	+++	++
P4	B	++	+	+++	+++
Sun	C	+++[1]	++	+++[1]	++
M. Phas	C	++	++	++	++
Musa	C	++	+	++	++
Straits	C	++	+	++	++
Caj	C	++	+	+++	++
Bean	C	++	+	++	++
Rhod	C	++	—	+++	++
Sw. P.C	C	++	—	++	++
Sw. P	C	++	—	++	++
G.G	C	+	—	++[2]	++
TcR	C	++	—	+++	+
Jun	C	++	—	+	+
Alb	C	—	—	—	+
Cit	C	++	—	++	—
Tob	C	++	—	++	—
Ses	C	+	—	—	—

+++ Very good. ++ Good. + Fair. — Poor.

The B strains again gave uniformly good results ; the C strains shewed appreciable variation. Photographs of sections of inoculated *Hevea* wood are reproduced on plate XXVIII, figures 1–3 ; the Cacao strain is typical of the B group, and the Sun and Ses strains shew the variation in penetrative power of members of the C group. The surface growth bore no relation to the amount of penetration, and in the rubber twigs in particular sclerotia were produced much more abundantly on the surface of a young twig than on an older one.

c. On leaves of bean

Young bean leaves were sterilised with mercuric chloride, washed in distilled water and placed in small flasks. They were inoculated with the following strains of the C group.

Cit	G.G	Ac
TcR	Sw. P.C	Musa
Jun	Bean	Caj
Alb	M. Phas	Tob
Ses	Rhod	Straits

1 Attempt to produce pycnidia ; botryose structure resembling that produced by Caj strain on *Cajanus* twigs.

2 Sclerotia produced by strain otherwise sterile.

They were examined after 14 days. In all cases except Ac and G.G the leaves were covered with numerous sclerotia from which pure cultures were recovered. The strains Ac and G.G grew well and covered the leaf with a sterile mycelium. Pycnidia were not observed.

d. On sweet potato wedges

All the strains under examination grew vigorously on sterilised sweet potato wedges. At the end of eight days it was found that the C strains had penetrated two–thirds of the substratum, filling it with sclerotia as in charcoal rot described by Taubenhaus (2). B strains in the same period had completely filled the wedge, which now consisted of a mass of black sclerotia. The A strain under examination had penetrated half the substratum, and the large sclerotia of the group were being formed in the tissues. Pycnidia were not observed.

e. On sweet potato tubers

All forms were found capable of attacking sweet potato tubers. Inoculations were made by the method of Granger and Horne (7) and examined after one month. A dry rot similar in nature to that described by Taubenhaus (2) was produced by all three groups. Sweet-potato tubers were also inoculated with the pycnidial form which had been obtained by saltation from the Caj strain (p. 232). Six cultures were made and were examined after one month. In the first to be examined the fungus had permeated the plug of potato tissue and had spread into the body of the tuber for several millimetres, producing a discoloured area. The plug contained numerous pycnidia, the spores of which were shrivelled probably from age. The mycelium accompanying the pycnidia was brown with characteristic cell shapes and much oil. Pycnospores were taken into culture on maize meal agar and they reproduced the pycnidial strain used for inoculation. In four others the fungus had made more progress and the appearance of the tuber resembled that of one attacked by charcoal rot. Further examination shewed that charcoal rot was actually present. The attacked tissue was black, and consisted of disrupted host cells permeated by a dark coloured mycelium, with characteristic cell shapes and much oil, and sclerotia. No pycnidia could be found. The sclerotia were taken into culture and reproduced the pycnidial form used for inoculation. The sixth inoculation failed.

INOCULATION EXPERIMENTS

The experiments about to be described had for their primary object the establishment of a direct connection between various sclerotial forms and their perfect stage, be it *Macrophomina Phaseoli* or no. With two exceptions the object failed ; pycnidia were obtained from the strain isolated from *Musa* and from the C strain of tea in addition to the isolations from bean, sunflower and pigeon pea which had been established previously. It is interesting to note that the two additional strains have sclerotia belonging to the C group. Though the experiments failed in their main object they throw light on certain aspects of the parasitism of *Rhizoctonia bataticola* and are considered worthy of reproduction. The prominence of bean and pigeon pea as host plants in these experiments is easily explained ; they are hosts of the pycnidial form and might be expected to produce it the more easily on that account.

Stem inoculations : pot experiments

Name of plant.	*Strain of Rhizoctonia used for inoculation.*	*Date.*	*Pot.*	*Treatment.*	*Result.*
Experiment 1					
Clitoria cajanifolia	Boga (B)	31.5.27	1	21 plants inoculated by wounds in axil of youngest leaf	Inoculations failed
			2	21 plants inoculated as above	do
			3	26 plants wounded but not inoculated (controls)	All healthy
Capsicum annuum (chilli)	Boga (B)		4	18 plants inoculated by wounds on upper stem	Inoculations failed
			5	11 plants inoculated as above	do
			6	15 plants wounded but not inoculated (controls)	All healthy
	All plants kept in inoculation chamber in shade.				
Experiment 2					
Clitoria cajanifolia	Bean (C) Culture grown from pycnospore	15.8.27	1	21 plants used in Experiment 1 Pot 1 inoculated by stem wounds	Inoculations failed
			2	26 plants used in Experiment 1 Pot 3 inoculated as above	do
			3	21 plants used in Experiment 1 Pot 2 wounded but not inoculated (controls)	All healthy

Name of plant.	*Strain of Rhizoctonia used for inoculation.*	*Date.*	*Pot.*	*Treatment.*	*Result.*
Capsicum annuum (chilli)	Bean (C) as above		4	18 plants used in Experiment 1 Pot 4 inoculated by stem wounds	Inoculations failed
			5	15 plants used in Experiment 1 Pot 6 inoculated as above	do
			6	11 plants used in Experiment 1 Pot 5 wounded but not inoculated (controls)	All healthy

All plants kept in inoculation chamber in shade.

Experiment 3

Phaseolus vulgaris (French bean)	Bean (C)	31.8.27	1	15 plants inoculated by stem wounds	28.9.27. 3 plants diseased; 12 healthy. *Pycnidia produced*
			2	12 plants inoculated as above	30.9.27 5 plants diseased, 7 healthy
			3	15 plants wounded only (controls)	14.10.27 All healthy

Pots 1 and 3 were kept in a moist chamber for the whole period of the experiment, and pycnidia were produced on the stems of the dead plants. Pot 2 was removed from the damp chamber as soon as the fungus was established, and sclerotia only were developed.

Percentage of success 29·6 %

Experiment 4

Phaseolus vulgaris (French bean)	TcR (C)	2.11.27	1	17 plants inoculated with stem wounds	Inoculations failed
	P_4 (B)		2	12 plants inoculated as above	All plants attacked and killed
	U_2 (A)		3	15 plants inoculated as above	Inoculations failed

Experiment 5

Phaseolus vulgaris (French bean)	TcR (C)	16.11.27	1	11 plants inoculated as above	do
	P_4 (B)		2	12 plants inoculated as above	9 plants killed 3 healthy
	U_2 (A)		3	14 plants inoculated as above	Inoculations failed

All plants kept in inoculation chamber in shade. The B strain was successful while the A and C strains were not. The attacked plants were quickly killed and their death was accompanied by a copious production of sclerotia in and on the stem. The growth of the fungus in the dead stem was downward toward the roots rather than upward.

Experiment 6

Phaseolus vulgaris (French bean)	Musa (C)	14.5.28	1	9 plants inoculated with stem wounds	Inoculations failed
	Cit (C)		2	10 plants inoculated as above	do

Name of plant.	*Strain of Rhizoctonia used for inoculation.*	*Date.*	*Pot.*	*Treatment.*	*Result.*
Experiment 7					
Phaseolus vulgaris (French bean)	Musa (C)	1.6.28	1	16 plants inoculated as above	Inoculations failed
	Cit (C)		2	16 plants inoculated as above	do

The plants were kept in the shade.

The wounds in all cases were covered with cotton wool which was kept moist. 14 days after inoculation the plugs were removed. All plants shewed a long narrow wound which was callusing over.

Experiment 8					
Phaselous vulgaris (French bean)	Tob (C)	29.8.28	1	6 plants inoculated at collar with severe wounds	28.9.28. 1 plant killed by bean fly (*Agromyza* sp.) 5 healthy
	Straits(C)		2	5 plants inoculated as above	1 plant killed by bean fly (*Agromyza* sp.) 4 plants healthy
	TcR (C)		3	5 plants inoculated as above	All healthy
	Musa (C)		4	5 plants inoculated as above	do
	Jun (C)		5	5 plants inoculated as above	do
	Clit (B)		6	6 plants inoculated as above	18.9.28 4 plants killed, 2 plants healthy
	Boga (B)		7	6 plants inoculated as above	4 plants killed, 2 plants healthy
	Hib (B)		8	6 plants inoculated as above	1 plant killed, 2 killed by bean fly (*Agromyza* sp.) 3 plants healthy
	H_{14} (B)		9	5 plants inoculated as above	5 plants killed

All plants were kept in an inoculation chamber in the shade. It will be noted that the successful strains all belong to the B group and that the C strains failed. All the plants killed by the fungus bore numerous sclerotia, which were isolated and found to give cultures of the B group. Most of the plants collapsed shortly after inoculation from the severity of the wounding, but those not killed by the bean fly or by the fungus had put out numerous adventitious roots above the point of inoculation and were quite healthy. It was found in all cases where severe wounds were inflicted that the plants collapsed, but collapse was by no means invariably followed by death.

Name of plant.	*Strain of Rhizoctonia used for inoculation.*	*Date.*	*Pot.*	*Treatment.*	*Result.*
Experiment 9					
Phaseolus vulgaris (French bean)	Bean (C)	6.10.28	1	8 plants inoculated at ground level with mycelium two days old and with slight wounding. 1 plant wounded only (control)	16.10.28 8 plants killed Control healthy
	Musa (C)		2	do	6 plants killed; 2 plants healthy. Control healthy
	Caj (C)		3	do	8 plants killed. *Pycnidia produced.* Control healthy.
	Tob (C)		4	do	8 plants killed. Control healthy.
	TcR (C)		5	do	8 plants killed *Pycnidia produced.* Control healthy
	Boga (B)		6	do	5 plants killed. 3 plants healthy. Control healthy
	H_{14} (B)		7	do	8 plants killed. Control healthy
	Clit (B)		8	do	6 plants killed, 2 plants healthy. Control healthy
	Hib (B)		9	do	3 plants killed, 5 plants healthy. Control healthy
	Ac. mel (A)		10	do	All healthy. Control healthy

All plants kept in inoculation chamber in shade. In two cases pycnidia of *Macrophomina Phaseoli* were obtained; on 5 plants out of 8 killed by the Cajanus strain, and on 2 plants out of 8 killed by the TcR strain. In all cases they were accompanied by sclerotia, which were found on all the plants killed. Isolation of pycnospores gave pure sclerotial cultures of *Rhizoctonia bataticola* of the C group with sclerotia of the size of those used for inoculation. It was again noted that initial collapse did not necessarily mean the subsequent death of the plant. In the moist atmosphere of the inoculation chamber the plants dropped their cotyledons before the latter were exhausted of food reserves, and many collapsed at the point of infection, while the upper part of the plant remained green and turgid. Subsequent recovery was by means of adventitious roots as in the last experiment.

It is of interest to note that the plants inoculated with the bean strain did not produce pycnidia.

Name of plant.	*Strain of Rhizoctonia used for inoculation.*	*Date.*	*Pot.*	*Treatment.*	*Result.*
Experiment 10					
Phaseolus vulgaris (French bean)	Bean (C)	30.11.28	1	7 plants inoculated at ground level with three-day old culture, with slight wounds. 1 plant wounded only (control)	20.12.28 7 plants killed Control healthy
	Tob (C)		2	do	do
	TcR (C)		3	do	5 plants killed, 2 plants healthy. Control healthy
	Musa (C)		4	do	1 plant killed, 6 plants healthy. Control healthy. *Pycnidia produced.*
	Clit (B)		5	do	3 plants killed, 4 plants healthy. Control healthy
	Hib (B)		6	do	6 plants killed, 1 plant healthy. Control healthy
	H_{14} (B)		7	do	7 plants killed. Control healthy
	Ac. mel (A)		8	do	1 plant killed, 6 plants healthy. Control healthy

All plants kept in moist chamber in shade. It will be noticed that, although this experiment was conducted under exactly the same conditions as the last, yet the strain which produced pycnidia in that experiment failed in this and *vice versâ*. The Musa strain killed only one plant, but that plant bore numerous pycnidia of *Macrophomina Phaseoli*, the spores of which, when taken into culture, gave pure growths of *Rhizoctonia bataticola* with sclerotia of the C group. All the dead plants bore numerous sclerotia corresponding to those used for inoculation. It was noticed that the B strains, when successful, penetrated further into the host plant than the C strain, particularly in a downward direction. In cases where infection did not take place, fungus hyphae were found growing inside the (hollow) stem of the host.

Stem inoculations : field experiments

A plot of *Cajanus indicus* growing in the laboratory compound and sown in April was inoculated in August with the following strains :

Tob	C	Clit	B	Ac. mel A
Straits		Boga		
TcR		Hib		
Musa		H_{14}		Control
Jun				

Three plants were inoculated with each strain and there were three control plants. The stem tissues were cut obliquely down to the wood about six inches from ground level and a large piece of culture (on maize meal agar) placed in the cleft. The inoculum was covered by a piece of cotton wool soaked in distilled water and the stem bound up with tape. The controls were treated in the same way except that they received no fungus.

After 20 days one of each three plants was cut back to the bud immediately above the wound. After 26 days a second plant was similarly cut back, the wrapping was removed and the stump was covered by a glass chimney, the mouth of which was packed with cotton wool. The chimneys were left in position for 16 days. This series was examined *in situ*, and in most cases there was a good development of callus between the cut strip and the stem. The fungus appeared not to have progressed at all. There was a slight exudation of gum round the wound in the cases of Hib, Boga, Clit, H_{14}, TcR and Tob. The third plant of each treatment was not touched until 54 days after inoculation, when the tape was removed and it was seen that the fungus had in no case made progress, and was at best confined to the flap of bark left when the inoculations were made, and which was now dead.

The plants which had been cut back put out new shoots above and or below the wound, but after one month from cutting back the new shoots began to die back. The death of the shoot was followed by the blackening and death of the whole stump, which was removed for examination. One after another of the stumps died back until three only were left. These three, by a curious coincidence, had been inoculated with the strains Ac. mel, Boga and Jun respectively; the coincidence arises from the fact that the strains in question belong respectively to the A, B and C groups. The two control plants which had been cut back died in the same way.

On examination the roots of the dead plants were found to be completely permeated by *Rhizoctonia bataticola*, and the inner cortex was full of sclerotia ; it was apparent, however, that the sclerotia were all of the B group irrespective of the strain with which the plant had been inoculated. The roots of the two dead control plants were similarly full of sclerotia belonging to a strain of the B group. This finding was confirmed by taking the sclerotia into culture. The operation proved to be not an easy one, for in every case an examination of root fragments showed the presence of the conidia of a species of *Fusarium*. Single sclerotia were washed in 0·5% sulphuric acid and put on to plain agar slants. The young growths were subcultured to maize meal agar, but in most cases gave cultures of the *Fusarium*, which had survived the

sulphuric acid treatment. However, sclerotia of *Rhizoctonia bataticola* developed in the plain agar cultures (in which medium *Rhizoctonia* apparently had the advantage of the *Fusarium*) and were found to belong to the B group with a mean diameter of 192μ. In every case the presence on the dead roots of *Rhizoctonia bataticola* (B group) and of a species of *Fusarium* was established.

The remaining third of the plants, which had not been lopped, may now be considered. Two months after inoculation a heavy storm broke down three of the plants, the stems of which snapped at the point at which they had been wounded. The plants were removed, and were healthy. Portions of root were sterilised on the outside with mercuric chloride (1 in 1,000) and were put in moist petri dishes. At the end of a month they were examined, and were found to bear the following fungi :—

1. Inoculated with Boga (B) strain
   Pellionella sp., *Neocosmospora* sp.
   Fusarium sp., *Cephalosporium* sp.
2. Inoculated with Tob (C) strain
   Rhizoctonia bataticola (B group)
   Neocosmospora sp., *Fusarium* sp.
   Cephalosporium sp.
3. Inoculated with Clit (B) strain
   Neocosmospora sp., *Fusarium* sp.
   Cephalosporium sp.

Further fragments treated in the same way developed only *Neocosmospora* and *Fusarium*.

At the same time root fragments of a healthy (and uninoculated) plant were treated in the same way and developed growths of a species of *Fusarium* and of *Cephalosporium*. It is possible that the *Neocosmospora*, *Fusarium* and *Cephalosporium* were forms of the same organism ; Nowell (4) has recorded *Neocosmospora* as a common growth on the roots of leguminous plants, and *Fusarium* is a common soil saprophyte. The rest of the inoculated plants, with the uncut control, continued to be healthy and in the course of time were removed after having produced flowers and pods. The three stumps which survived the lopping put out new shoots which grew vigorously. In the following February, six months after inoculation, they were again cut right back consequent upon a severe attack of *Woroninella umbilicata*. The whole top down to the lowest visible bud was removed and from this treatment one plant (inoculated originally with the Juniper strain) failed to recover. The dead plant was removed and the lower part of the tap root found to be

permeated with sclerotia of *Rhizoctonia bataticola* (B group). The lateral roots did not shew the presence of the fungus. Sclerotia were isolated and gave pure cultures of the B group. The two remaining plants are still healthy, eight months after inoculation.

The above experiment was repeated, using the same strains except that Straits was replaced by Bean, and Jun by Caj. On this occasion one plant only was inoculated with each strain and three day (mycelial) cultures of the fungus were used. Six days after inoculation the plant inoculated with Ac. mel was broken down by heavy rain. The stem snapped at the point of inoculation but the wrapping tape remained intact. The plant was not removed, but another plant was inoculated with the Ac. mel strain. Three months after inoculation the plants were cut back consequent upon a severe attack of *Woroninella umbilicata* (previously mentioned) and all the foliage was removed. The plants all recovered (including the broken plant) and are now growing vigorously, six months after inoculation.

The foregoing experiments, both in field and greenhouse, indicate that except under special circumstances the strains of *Rhizoctonia bataticola* under observation (and they may be considered a representative sample) are not capable of parasitizing stems of pigeon pea and bean. Where success was obtained it was not consistent, and a strain which succeeded on one occasion failed a second time under apparently identical conditions and for no apparent reason. The field experiments with pigeon pea are particularly interesting although the results obtained were outside the aim of the experiment. The consistent presence of sclerotia of a B strain, even in the control plants, means that the stem inoculations failed ; the death of only the lopped plants indicates that the B strain which was obtained from their roots was at best a weak parasite, requiring probably the death of the root-tips following on lopping to obtain a hold on the plant. The fungus may have been present in the soil of the plot, although preliminary isolations from soil suspensions have failed to produce it. It is also possible that the fungus was already present in a mycorrhizal form in the roots of the pigeon pea ; fungus hyphae have been observed in small, apparently healthy pigeon pea roots, and attempts are being made to isolate such hyphae. It is, however, interesting to note in this connection that "pelotons" similar to those figured by Rayner (12) and others from mycorrhizal Rhizoctonias have been observed in young cultures of the B strain under discussion. No evidence in favour of either of these possibilities can be drawn from the attempts recorded above to isolate fungi from root fragments ; *Rhizoctonia bataticola* occurred only once, while *Fusarium*, which has not been recorded as an endophyte and which is known to be a

common soil inhabitant was present consistently. It must be concluded that the surface sterilisation of the root fragments was ineffective. The inconsistency of the results of the inoculations on bean may be the result of a loss of virulence by the fungus as a result of generations of artificial culture ; such occurrences are not uncommon. It is just as likely, however, that the conclusions of Buddin and Wakefield quoted on page 225 are equally applicable to *Macrophomina Phaseoli* ; the plasticity of this fungus in culture has been amply demonstrated.

Seedling inoculations

1. With French bean (*Phaseolus vulgaris*)

French beans were sterilised externally in mercuric chloride (1 in 1,000) and germinated in sand. At the same time a plate culture of the fungus required for the experiment was prepared. On the second day a glass lamp chimney was placed upright in a pot of soil and filled with sterilised sand to within one inch of the top. On this sand was placed a layer of fungus culture, cut from the prepared plate, which completely covered the sand. The chimney was then filled up with sand, and the germinated bean placed on top (Text fig. 3). Water was supplied by a continuous slow drip from above. The strains Bean, Citrus and Cajanus were used in the experiment. Three seedlings were treated with the

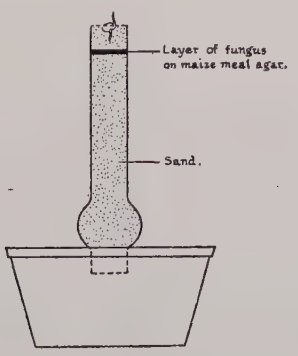

Fig. 3

Bean strain, six with Citrus, and three with Cajanus. Negative results were obtained in all cases but one, in which the seedling collapsed after six days. The collar was blackened and rotten, and bore numerous sclerotia of a C strain, but the roots, which were brown and shrivelled, were full of the mycelium of a species of *Pythium*. In the other cases the plants lived or died according as the roots had or had not reached the soil of the pot by the time the cotyledonary food supply was exhausted.

Examination of the wilted plants showed that in all cases the roots were quite healthy. The fungus grew well, and when examined was a mass of sclerotia among which many of the bean roots had passed.

2. With pigeon pea (*Cajanus indicus*)

Test tubes were three-quarters filled with plain agar (0·5%), sterilised and inoculated with the Caj (C) strain. At the same time seeds of pigeon pea were surface–sterilised with mercuric chloride (1 in 1,000) and germinated on sand. When the seeds were germinated the plugs were removed from the tubes, and the agar covered by a layer of sterilised sand, on top of which the germinated seed was placed. The sand was kept moist with distilled water and proved a successful barrier against external contamination. Twenty tubes were inoculated, and four tubes without fungus but otherwise identical served as controls. Growth was good and the roots of the pigeon pea quickly penetrated the agar, of which the top inch was permeated by fungus hyphae. In many cases the actual contact of roots and fungus was shown by black discolorations on the former, but the roots were not killed. The cultures were left until the agar began to dry out, when the bottom of the tube was broken and the whole potted out. Two plants were removed and examined, but root sections failed to show penetration by the fungus. The potted plants continued to be healthy, and flowered and produced pods, after which they were removed.

The above method was later improved upon. Breaking the tubes before potting entailed the risk of damage to the plant roots, and the confined space in the tube did not permit of free growth. In the amended technique wide glass tubes were filled with plain agar (1%) to the depth of one inch, and sterilised. On being removed from the autoclave the

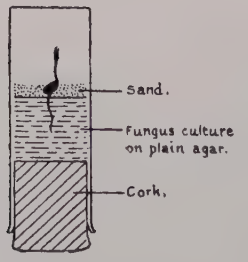

Fig. 4

cotton plug was quickly replaced by a tightly–fitting cork and the tubes were inverted. When the agar had solidified the tube was cut in two by

means of a diamond, the medium was inoculated with the Caj (C) strain and the tube was plugged. It was now in the same case as the tubes in the previous experiment except that, when it became desirable to put out the plants in the field, all that was necessary was to remove the cork, and there was no risk of damage to the plant. Pigeon pea seeds were surface-sterilised and germinated. When the fungus was firmly established (it was found that a solid growth of half an inch in depth could be obtained, but never more; conditions of aeration inside the medium possibly prevented further growth) the plug was removed, a surface cover of sterilised sand introduced, and the germinated seed placed on top (Text fig. 4). When the radicle of the pea reached the cork (about ten days) the latter was removed and the tube planted out in a field plot. Nineteen tubes were so prepared, with five additional tubes as controls, and all were planted in the same field plot. Eighteen days after planting out one plant died and was removed. On washing away the earth, the collar of the seedling was found to be in close contact with the inoculum, and was dried up and covered with pycnidia of *Macrophomina Phaseoli*. The cortex of the tap root was cracked longitudinally for a distance of one inch below the collar, and the roots issuing from this portion were brown and bore hyphae, sclerotia and pycnidia. Pycnospores were cultured and gave pure sclerotial growths of a C strain agreeing with that used for inoculation. One of the control seedlings was removed and the same longitudinal cracking below the collar was observed. A side root was sectioned but no fungus was found, and the plant was returned to the plot.

Four months after planting out, when the plants were four feet high and looking very healthy, one of the inoculated plants shewed signs of wilting. Six days later, when it was completely wilted but the leaves had not yet fallen, it was removed. The root system was found to be poorly developed and the plant was washed and left on the laboratory bench for examination. Next morning four inches of the tap root from the collar downwards were covered with a white mycelium, which was cultured and yielded a pure growth of a species of *Fusarium*. The lower part of the tap root was permeated by sclerotia which were found to belong to the B group and to be identical with those obtained from the pigeon pea plants subjected to stem inoculations. The rest of the plants continued to be healthy and equal in appearance to the uninoculated plants, and were eventually removed after they had flowered and produced pods.

The results of the above experiments bear out the conclusions drawn from the stem inoculations previously recorded, that special conditions are required for successful inoculation with *Rhizoctonia bataticola*.

DISCUSSION

While there are characteristics among strains of the C group so distinct and so regular in occurrence as to enable anyone familiar with them to identify strains at sight, there is nevertheless no correlation between any two differences, and it is impossible without further evidence to subdivide the group. A consideration of the six strains which have definitely been connected with the pycnidial form *Macrophomina Phaseoli*, namely Cajanus, TcR, Bean, M. Phas, Musa and Sunflower, shews them to include forms having green or white mycelium in the early stages, and producing either no colour or pink or wine-red coloration on modified Dox's agar. They agree in producing sclerotia on plain agar, but when arranged according to sclerotial size (table I) they occur in two groups, which are separated from one another by a group which produces no sclerotia on plain agar. If then there exist such differences in the forms which, by virtue of their connection with the pycnidial stage, are without doubt the same organism, the same differences must be admitted to be of little importance among the forms which have hitherto not been connected with the pycnidial stage. It would appear to follow that the differences in question are occasioned by the host plants from which the strains were isolated, but against that view is the fact that the strains Bean and M. Phas, both occurring on beans, differ in their behaviour on modified Dox's agar. The same is true of the strains Sw. P.C and Sw.P from sweet potatoes, one of which produces sclerotia on plain agar, while the other does not. It is true that M. Phas and Sw.P came from America and Bean and Sw.P.C from Ceylon, and in view of the amply demonstrated plasticity of the fungus this fact may be sufficient to account for the difference in behaviour.

The saltating strains include forms which produce sclerotia on plain agar and forms which do not, and some of the strains which do not produce sclerotia have not shewn any other variation from the normal. When grown on plant tissues the majority of the forms which do not produce sclerotia on plain agar are among the less successful strains, but Tob and Sw.P have given good results. Inoculation experiments shew Tob (a non-sclerotial saltating strain) to be consistently better than Musa, which has produced pycnidia.

There is little or no doubt that the strains of the B group are one and the same organism. They vary only in sclerotial size, and the variation is inappreciable. It remains to be seen whether the A strains are homogeneous.

SUMMARY

1. Twenty-seven strains of *Macrophomina Phaseoli* (Maubl.) Ashby (=*Rhizoctonia bataticola* (Taub.) Butl.) have been examined and have been divided into three groups by mean sclerotial size in culture. The groups are distinct and readily distinguishable one from another.
2. Considerable variation has been shewn by members of the smallest (or C) group, but differences are diverse in character and cannot be correlated.
3. Pycnidia of *Macrophomina Phaseoli* have so far been connected only with the smallest group, and it is considered possible that the other groups may have distinct perfect stages. Until some knowledge is obtained of the higher stages of the A and B forms, however, it is advisable on morphological grounds to retain the present arrangement, whereby all three groups are regarded as forms of one species and are called *Rhizoctonia bataticola*.
4. There has arisen by saltation a form which gives pycnidia of *Macrophomina Phaseoli* in culture, either with or without sclerotia. This form produces a rot of sweet potato tubers similar to charcoal rot, with the production of either pycnidia or sclerotia in the tissues of the host.
5. The fungus *Macrophomina Phaseoli* has been shewn to be extremely plastic in culture. It may be that a similar plasticity in its pathological action will account for the inconsistency of experimental results obtained by the present writer and others.

My thanks are due to Messrs. Ashby and Mason of the Imperial Bureau of Mycology for help in diagnosis, and to Messrs. Bertus and Alwis of this division for the photographs and drawings respectively.

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EXPLANATION OF PLATES

Plate XXV—Sclerotia

Fig. 1 Normal culture of C strain on maize meal agar. ×1
Fig. 2 Normal culture of B strain on maize meal agar. ×1
Fig. 3 Normal culture of A strain on maize meal agar. ×1
Fig. 4 Culture of C strain on Difco prune agar, shewing concentric zoning ×1.
Fig. 5 Section of sclerotia of C strain × 40
Fig. 6 ,, ,, B ,, × 40
Fig. 7 ,, ,, A ,, × 40
Fig. 8 Section of C sclerotium × 280
Fig. 9 ,, B ,, × 280
Fig. 10 ,, A ,, × 280

Plate XXVI—Aberrant strains

Fig. 1 Alb (C) on Potato dextrose agar shewing sterile quadrant × ½
Fig. 2 do Prune agar × ½
Fig. 3 Alb (C) sterile saltant on prune agar shewing dendroid form × ½
Fig. 4 Boga (B) on Prune agar shewing lobing × ½
Fig. 5 do on maize meal agar × ½

Plate XXVII

Figs. 1–5 Comparative penetration of *Cajanus* twigs by strains of *Rhizoctonia bataticola* × 40
Fig. 1 Alb (C); Fig. 2 TcR (C); Fig. 3 Caj (C); Fig. 4 Hib (B); Fig. 5 Ac. mel (A).
Fig. 6 Mixed pycnidia and sclerotia of Caj saltant × 40
Fig. 7 Pycnidium from do × 160

Plate XXVIII

Figs. 1–3 Comparative penetration of *Hevea* twigs by strains of *Rhizoctonia bataticola* × 40
Fig. 1 Ses (C) ; Fig. 2 Sun (C) ; Fig. 3 Cacao (B).
Figs. 4–6 Sclerotial primordia of a C strain ; one day old cultures on (Difco) malt extract agar × 1400

Plate XXIX

Cell shapes formed by guinea grass strain on prune agar × 400

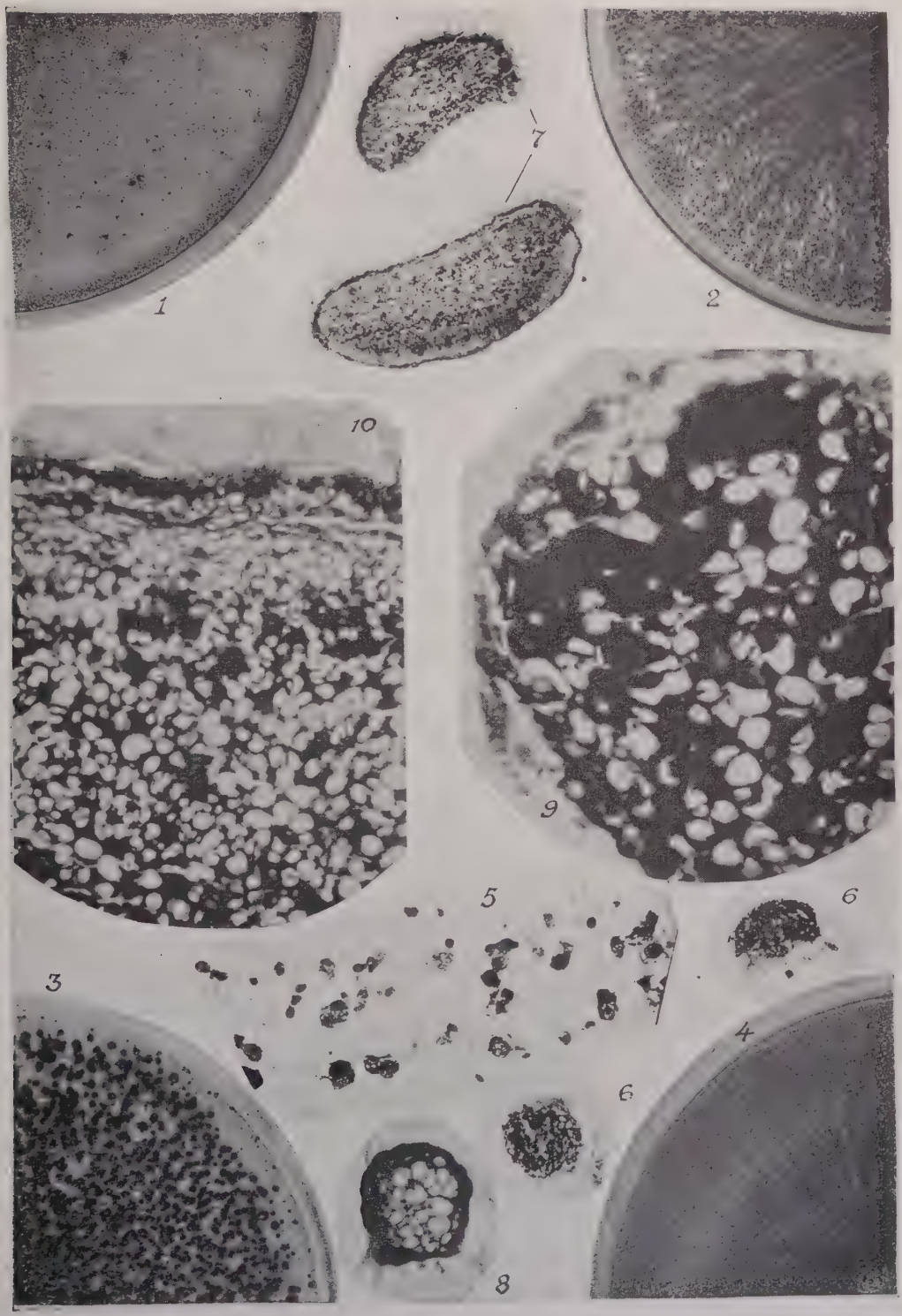
Plate XXX

Figs. 1–5 Sclerotial primordia of a C strain on malt extract agar × 1000
Figs. 1–3 from one-day old culture
Fig. 4 ,, two ,, ,, ,,
Fig. 5 young sclerotium from three-day old culture
Figs. 6–7 "Pelotons" from young culture of an A strain × 200
Fig. 6 from one-day old culture
Fig. 7 ,, two ,, ,, ,,

Plate XXXI

Normal and pycnidial forms of Caj strain on twigs of *Cajanus indicus* × 1
Fig. 1 Pycnidial form
Fig. 2 Normal

P Pycnidia S Sclerotia.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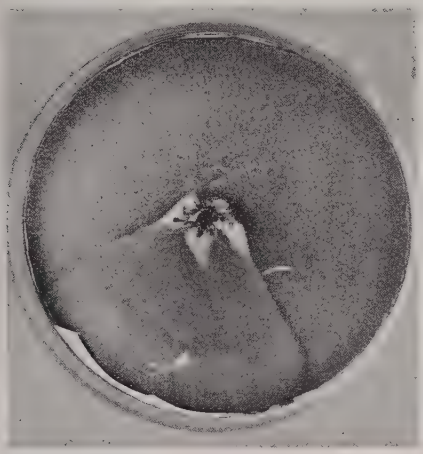

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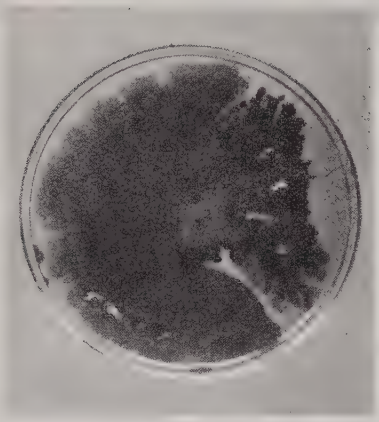

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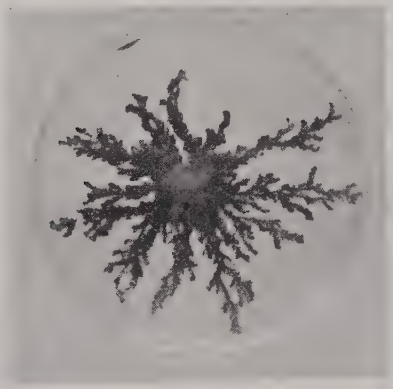

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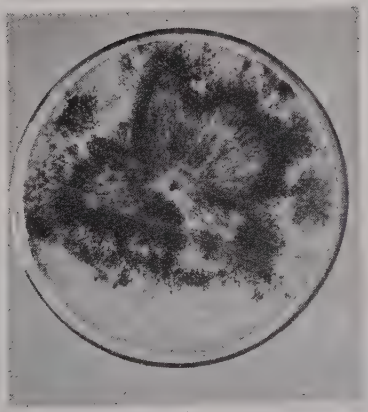

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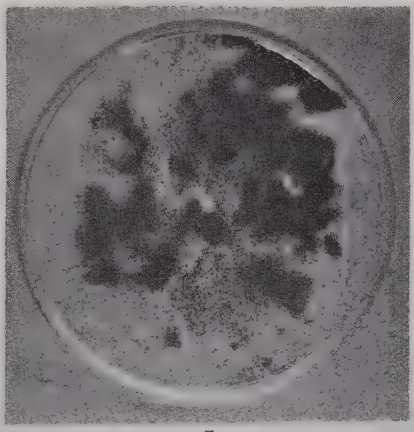

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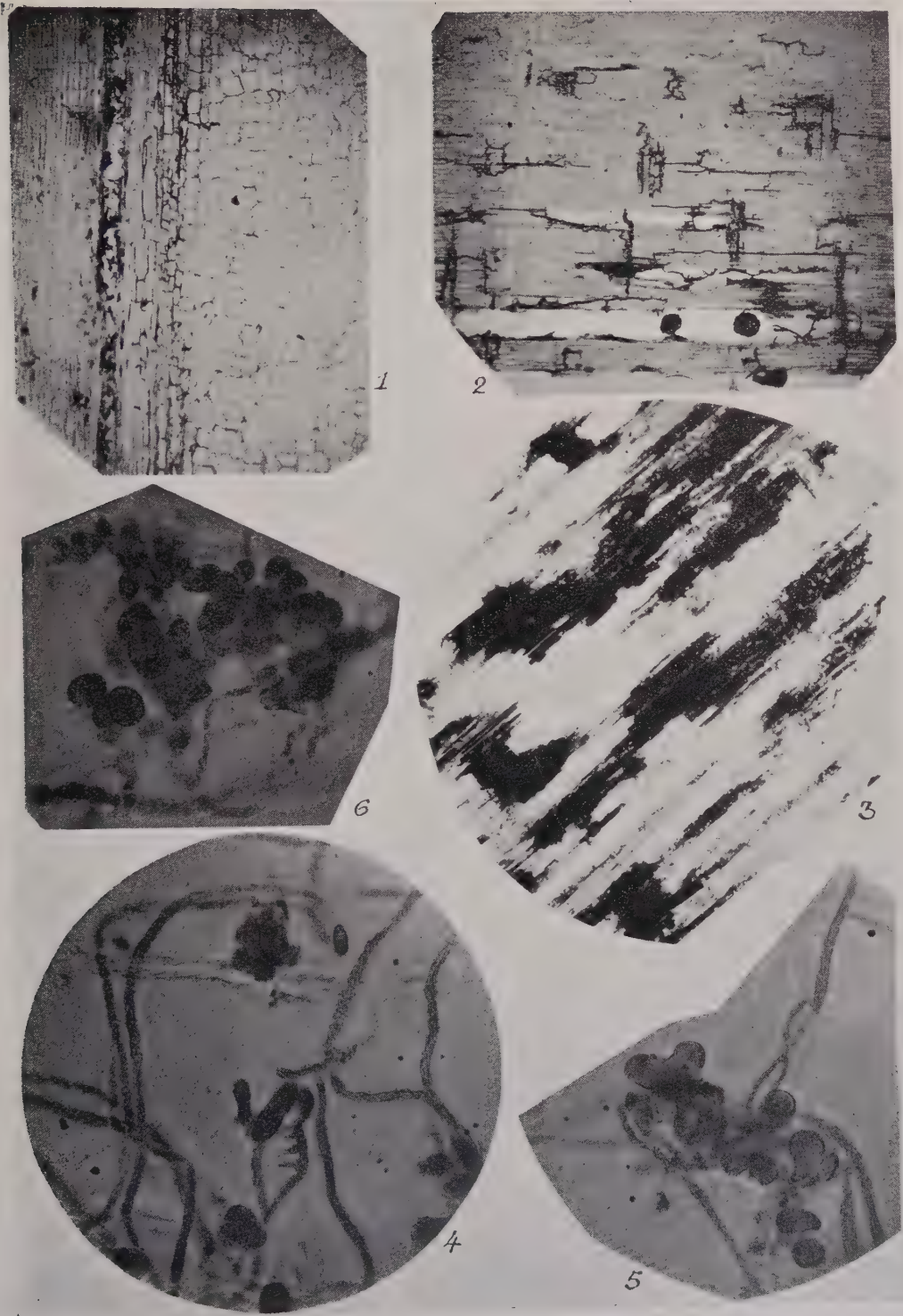
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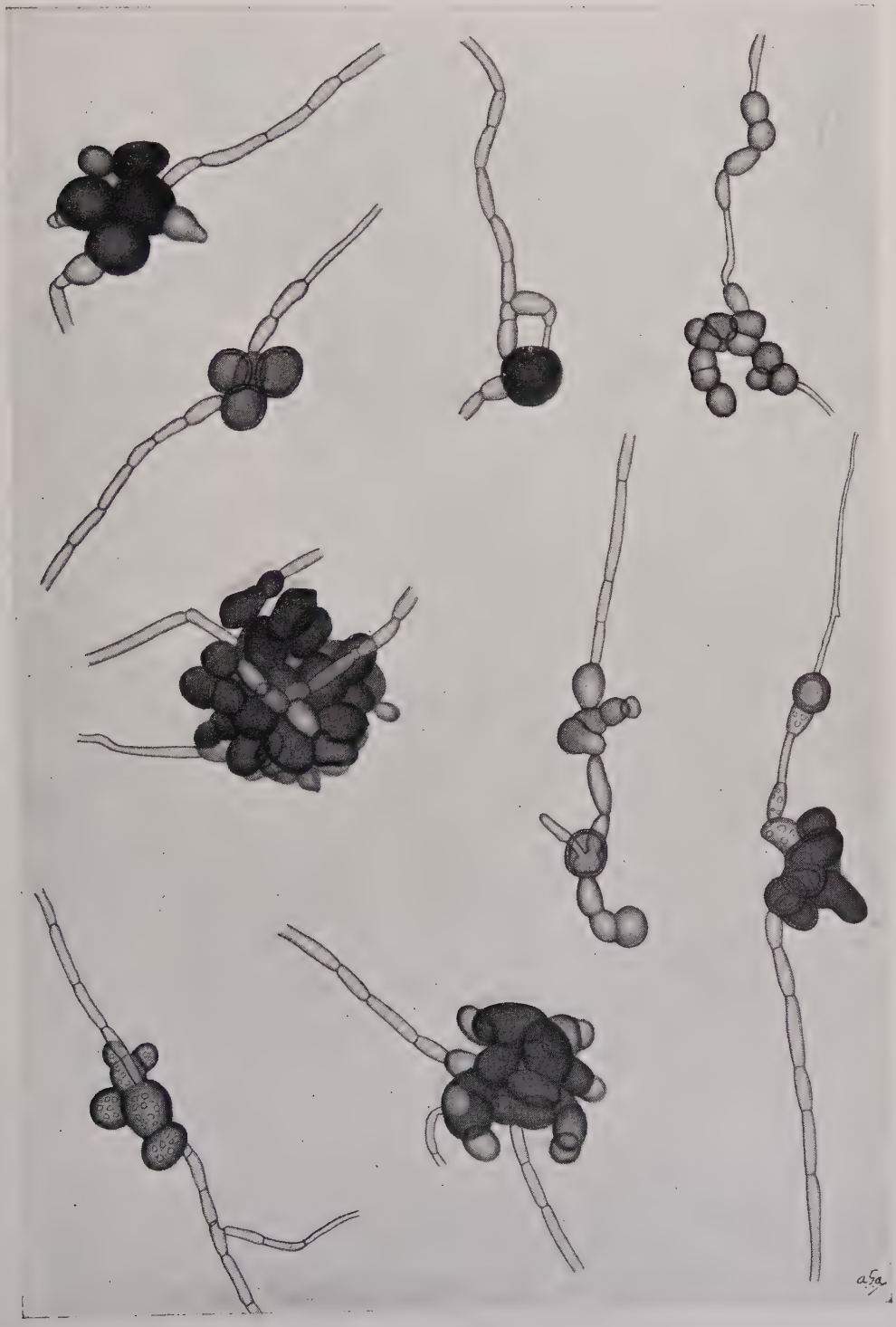

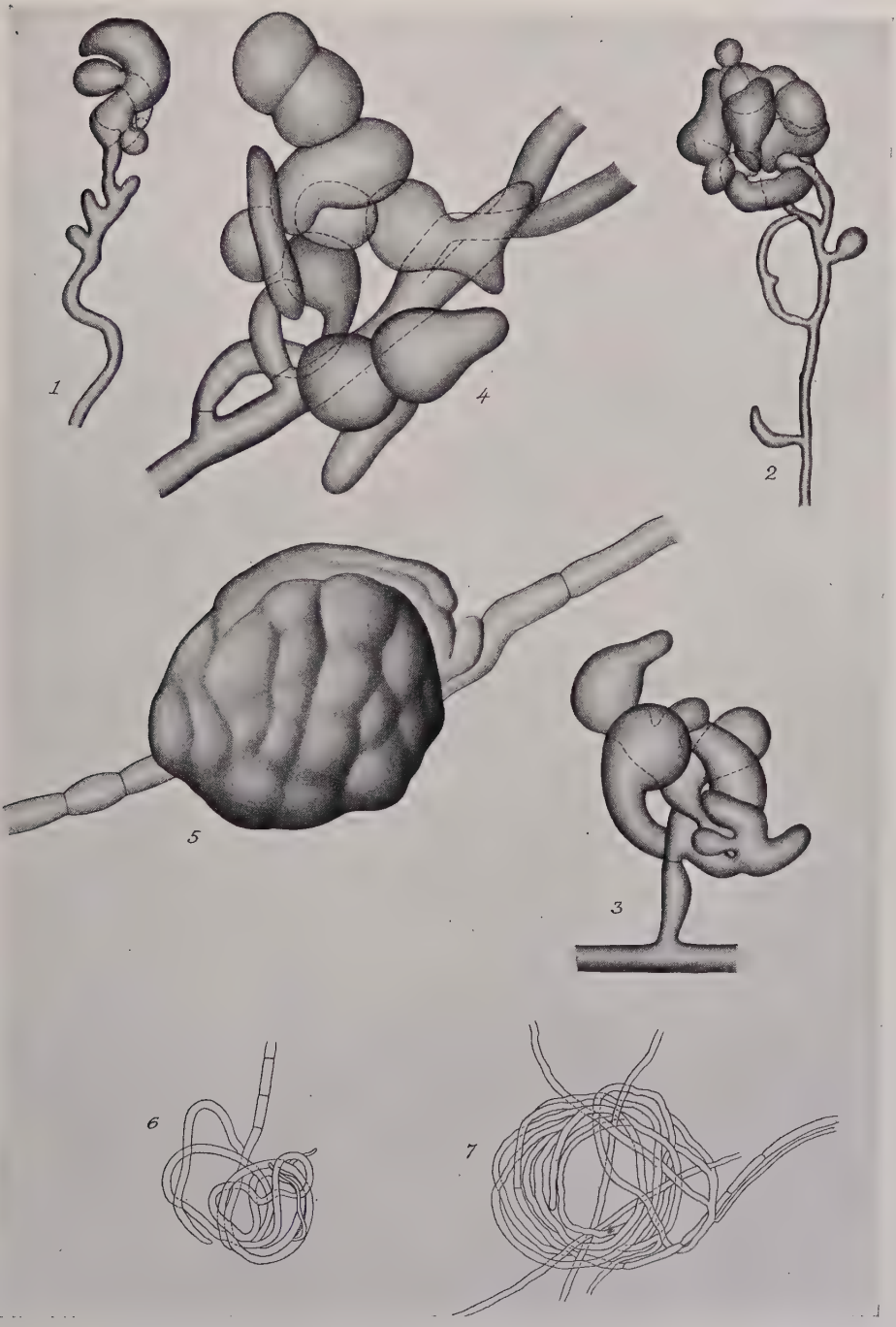
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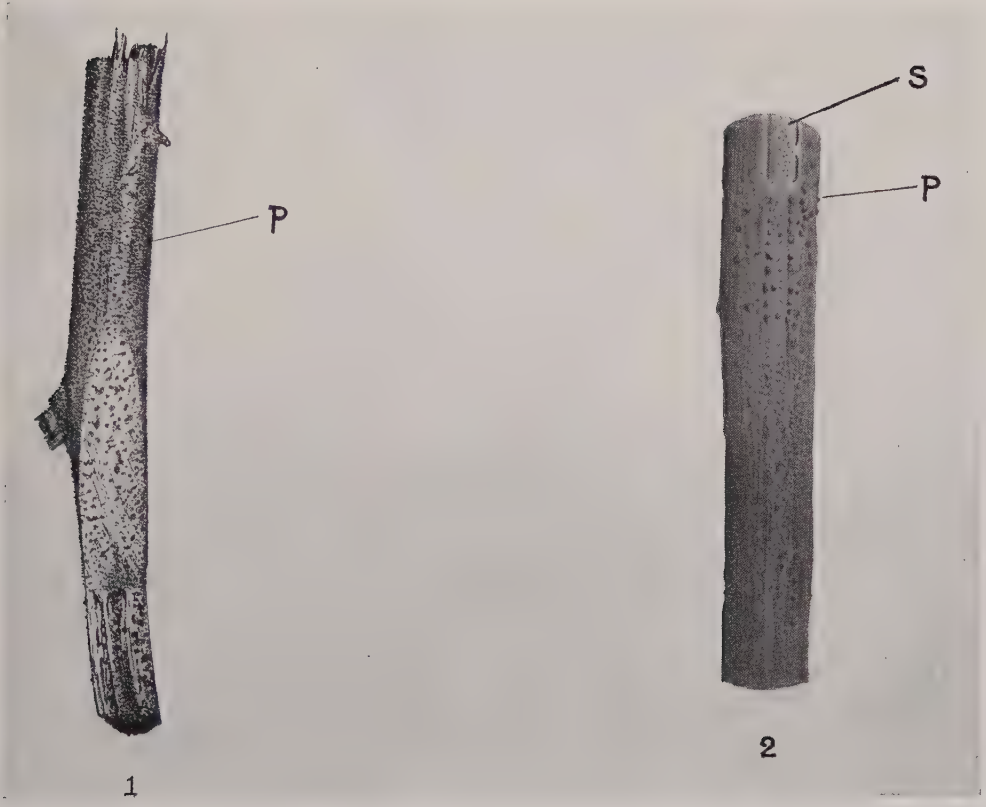
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Notes on Ceylon Diatoms. I

BY

B. W. Skvortzow, of Harbin, China

WITH THREE PLATES

By the kindness of Mr. A. H. G. Alston, Systematic Botanist of the Department of Agriculture, Peradeniya, Ceylon, I have been enabled to examine a number of gatherings of Diatoms from that district which he has most obligingly collected. The result is very pleasing, as many new and interesting species have thus been revealed, and considerable additional knowledge of the distribution of known forms has been attained. The Diatoms from Ceylon are of the greatest interest.

During recent years a considerable amount of work has been done on the Freshwater Algae of Ceylon, but our knowledge of their distribution still remains very fragmentary and incomplete. A list of freshwater Diatoms of Ceylon is given in W. and G. West's work "A Contribution to the Freshwater Algae of Ceylon" in Trans. Linn. Sc. of London, vol. 4, part 3, 1902. Nearly all the Diatoms listed by W. and G. West were of cosmopolitan nature and the most interesting were : *Actinella punctata* Lewis known from U.S.A., Baikal, Europe and Ceylon ; *Desmogonium Rabenhorstianum* Grun. known from W. Indies, the Island of Banca and Ceylon ; *Terpsinoe musica* Ehrenb.—W. Indies, China, India and Ceylon.

Some of the Diatoms observed in several of Mr. Alston's gatherings were essentially tropical in character and present great similarity to those of India, Sumatra, Java and the Malayan region. The presence in Ceylon of *Cerataulus thermalis* and var. *sinensis*, is highly interesting. The last variety is known from China and the island of Socotra. Among the freshwater species a considerable number of brackish water Diatoms were observed.

My first note on Ceylon diatoms includes a list of 99 forms found in the following gatherings :—

1. On *Pistia* roots in *Victoria regia* tank in Peradeniya Gardens. 7.8.26.
2. Mud from a ditch near the Orchid House, Peradeniya. 7.8.26.

3. Mud from paddy field Udagama near Peradeniya. 8.8.26.
4. Roots of *Pistia* from Sitavaka Ela, near Hambantota. 21.8.26.
5. Mud from stream at Kottava, Southern Province. 17.8.26.

Melosira undulata Kütz. Plate XXXII, fig. 1.

Length, 0·059 mm., breadth, 0·0408 mm. Habit. Java, Japan, Europe (fossil). 2.

Cerataulus thermalis (Menegh.) Ralfs. (Plate XXXII, figs. 2, 3, 5.)

Frustulis solitariis vel in catenas consociatis, cylindricis. Valvis fragilibus, subtilibus, setis cornubusque duabus praeditis. Diameter 0·045–0·065 mm. 1.

Cerataulus thermalis var. **sinensis** (Grun.) Forti forma **ceylonica** forma nova. (Plate XXXII, figs. 4, 6, 7.)

Frustulo ventro cylindrico, dense punctato, valvis circularibus rotundatis, setis cornubusque ternis et quaternis praeditis. Setis centro magis quam margini approximatis, evidentissimis. Diam. valvarum 0·2–0·23 mm. Habit. The typical var. *sinensis* was found in China in freshwater (Grunow, New Diatoms from Honduras, Micros. Jour. Oct. 1. 1877, p. 183–185. Pl. CXCVI, fig. 3 ; A. Forti, Contribuzioni Diatologiche. 9. Venezia. 1910, p. 22–23). 1.

Terpsinoe musica Ehrenb. (Plate XXXII, figs. 22–23.)

Length, 0·136 mm., breadth, 0·068 mm. 1.

Synedra familiaris Kütz.

Length, 0·062 mm., breadth, 0·012 mm. 2.

Synedra acus Kütz. var. **delicatissima** W. Smith.

Length, 0·251 mm., breadth, 0·006 mm. Striae, 9 to 10 in 0·01 mm. 4.

Synedra affinis Kütz. var. **obtusa** Hustedt.

Length, 0·154 mm., breadth, 0·005 mm. Striae, 11 to 12 in 0·01 mm. 1.

Synedra Ulna (Nitzsch.) Ehrenb.

Length, 0·13 to 0·2 mm., breadth, 0·009 mm. Striae, 9 in 0·01 mm. 2.

Synedra Ulna var. **subaequalis** Grun.

Length, 0·18 to 0·187 mm., breadth, 0·006 mm. Striae, 15 to 17 in 0·01 mm. 1, 2.

Eunotia major W. Smith.

Length, 0·102 to 0·158 mm., breadth, 0·008 to 0·01 mm. Striae, 11 to 12 in 0·01 mm. 2, 4.

Eunotia veneris Kütz. var. **obtusiuscula** Grun.

Length, 0·019 mm., breadth, 0·004 mm. Striae, 15 in 0·01 mm. 4.

Eunotia monodon Ehrenb.

Length, 0·049 to 0·053 mm., breadth, 0·007 to 0·0085 mm. Striae, 9 to 12 in 0·01 mm. 1, 2, 4, 5.

Eunotia formica Ehrenb.

Length, 0·097 mm., breadth, 0·014 mm. Striae, 10 to 11 in 0·01 mm. 4.

Eunotia formica var. **ceylonica** var. nov. (Plate XXXII, figs. 8, 9.)

Valvis 0·23 mm. longis, 0·085 mm. latis, ad ventrem leniter inflatis, cum polis vastis, rotundatis. 4.

Eunotia ceylonica sp. nov. (Plate XXXII, figs. 10, 11, 12.)

Valvis linearibus, modice inflexis, ad marginem, parallelis, 0·2–0·215 mm. longis, 0·012 mm. latis, cum polis obtusis rotundatis. Strialis transversis, 6–7 in 10 mikron. 3, 4.

Eunotia ceylonica var. **bigibba** var. nov. (Plate XXXII, fig. 13.)

Valvis modice inflexis, 0·19 mm. longis, 0·012 mm. latis. Striae, 7–8 in 10 mikron, ad dorsum bigibba. 4.

Eunotia Frickei Hustedt. var. **ceylonica** var. nov. (Plate XXXII, fig. 14.)

Valvis leniter flexis 0·052 mm. longis, 0·0068 mm. latis. Striae, 8 in 10 mikron ad marginem parallelis, cum polis obtusis inflatis. Habit. *E. Frickei* is found in the Demerara River (Atlas Diat. Taf. 288, figs. 1–5). 2

Eunotia praerupta Ehrenb. var. **curta** Grun.

Length, 0·021 mm., breadth, 0·005 mm., Striae, 15 in 0·01 mm. 4.

Eunotia gracilis Ehrenb.

Length, 0·079 to 0·136 mm., breadth, 0·0034 to 0·0039. Striae, 15 to 18 in 0·01 mm. 4, 5.

Eunotia pectinalis Kütz.

Length, 0·045 mm., breadth, 0·005 mm. Striae, 11 to 12 in 0·01 mm. 5.

Eunotia pectinalis var. **ventralis** (Ehrenb). Hustedt.

Length, 0·139 mm., breadth, 0·009 mm. Striae, 6 in 0·01 mm. 4.

Eunotia pectinalis var. **undulata** Ralfs.

Length, 0·044 mm., breadth, 0·0085 mm. Striae, 9 in 0·01 mm. 4.

Eunotia Alstonii sp. nov. (Plate XXXII, fig. 15).

Valvis linearibus, modice inflexis, ad marginem parallelis, 0·125 mm. longis, 0·006 mm. latis. Striae, 18 in 10 mikron, cum polis obtusis ad nodulus gibbosus. 5.

Cocconeis placentula Ehrenb.

Length, 0·018 mm., breadth, 0·012 mm. 1, 4.

Cocconeis placentula var. **euglypta** Cleve.

Length, 0·028 mm., breadth, 0·015 mm. Striae, 17 in 0·01 mm. 1.

Achnanthidium lanceolatum Bréb. (Plate XXXIII, fig. 17).

Length, 0·018 to 0·02 mm., breadth, 0·0085 mm. Striae, 12 in 0·01 mm. 2.

Achnanthidium lanceolatum var. **dubia** Grun.

Length, 0·0187 to 0·204 mm., breadth, 0·0068 to 0·007 mm. Striae, 16 to 17 in 0·01 mm. 2, 5.

Achnanthes andicola (Cleve) Hustedt.

Length, 0·023 mm., breadth, 0·006 mm. 2.

Achnanthes brevipes Ag. var. **intermedia** Kütz.

Length, 0·074 mm., breadth, 0·012 mm. Striae, 9 in 0·01 mm. 1.

Achnanthes exigua Grun.

Length, 0·0119 mm., breadth, 0·004 mm. 2.

Caloneis fasciata Lagstr.

Length, 0·051 mm., breadth, 0·0085. Striae, 22 to 25 in 0·01 mm. 1.

Diploneis ovalis Hilse.

Length, 0·0306 mm., breadth, 0·017 mm. Striae, 7, 5 in 0·01 mm. (locality ?)

Diploneis ovalis var. **pumila** Grun.

Length, 0·0255 mm., breadth, 0·013 mm. Striae, 11 to 12 in 0·01 mm. 5

Diploneis elliptica Kütz.

Length, 0·0459 mm., breadth, 0·021 mm. Striae, 6 in 0·01 mm. 2.

Neidium affine Ehrenb. var. **genuina** Cleve forma **ceylonica** forma nova. (Plate XXXII, fig. 24).

Valvis elongatis cum polis subrostatis, 0·095–0·097 mm. longis, 0·019 mm. latis. Striae, 18–20 in 10 mikron. E grege forma *xamica* Cleve. A.S. Atlas Diatom. Taf. XLIX, fig. 1. 3.

Neidium Kozlowi Mereschkovski var. **baikalensis** Skvort. and Meyer. forma. (Plate XXXII, fig. 27).

Length, 0·044 mm., breadth, 0·012 mm. Habit. Baikal lake. 3.

Neidiun Kozlowi var. **ceylonica** var. nov. (Plate XXXII, fig. 26).

Valvis lanceolatis cum polis productis et acuminatis, 0·054–0·055 mm. longis, 0·013–0·014 mm. latis. Striae, obliquis, 25 in 10 mikron. 3.

Mastogloia Smithii Thw. var. **conifera** Brun.

Length, 0·0306 to 0·0425 mm., breadth, 0·012 to 0·0153. Striae, 28 to 30 in 0·01 mm. 1.

Navicula pelliculosa (Bréb.) Hilse var. **ceylonica** var. nov. (Plate XXXII, fig. 25).

Valvis ellipticis cum polis rotundatis, 0·015–0·016 mm. longis, 0·0068–0·007 latis, cum longitudinales striis ornatis. Habit. *N. pelliculosa* is found in Germany and France in freshwater. 2.

Navicula subtilissima Cleve forma **baikalensis** Skvort. and Meyer. (Plate XXXII, fig. 19).

Length, 0·044 mm., breadth, 0·01 mm. 3.

Navicula viridula Kütz.

Length, 0·061 mm., breadth, 0·01 mm. Striae, 9 in 0·01 mm. 5.

Navicula viridula var. **slesvicensis** Grun.

Length, 0·037 mm., breadth, 0·008 mm. Striae, 12 in 0·01 mm. Habit. Brakish water form. 2.

Navicula viridula var. **rostellata** Kütz.

Length, 0·044 to 0·051 mm., breadth, 0·0085 to 0·01. Striae, 10 to 12 in 0·01 mm. Brackish water form. 2, 5.

Navicula gracilis Ehrenb. var. **schizonemoides** Y. Heurck.

Length, 0·058 mm., breadth, 0·0085. Striae, 12 in 0·01 mm. 4.

Navicula digito–radiata Greg. forma **ceylonica** forma nova. (Plate XXXII, fig. 28).

Valvis lanceolatis, 0·051 mm. longis, 0·0085 mm. latis. Striae, subradiantes, 12 in 10 mikron. *N. digito–radiata* is known as a marine and brackish form. 2.

Navicula radiosa Kütz. var. **tenella** Bréb.

Length, 0·034 mm., breadth, 0·006 mm. Striae, 15 in 0·01 mm. 2.

Navicula oblonga Kütz. var. **acuminata** Grun. (Plate XXXII, fig. 16).

Length, 0 064 mm., breadth, 0·0085 mm. Striae, 9 in 0·01 mm. 5.

Navicula oblonga var. **subparallela** Rattray forma. (Plate XXXII, fig. 17).

Length, 0·068 mm., breadth, 0·016 mm. Striae, 10 in 0·01 mm. 5.

Navicula amphibola Cleve. (Plate XXXII, fig. 18.).

Length, 0·0306 mm., breadth, 0·012 mm. Striae, 21 in 0·01 mm. 5.

Navicula Bacillum Ehrenb. var. **minor** Y. Heurck.

Length, 0·0238 mm., breadth, 0·0065 mm. 2.

Navicula pusilla W. Smith.

Length, 0·074 mm., breadth, 0·018 mm. Striae, 10 to 11 in 0·01 mm. 1.

Navicula ceylonica sp. nov. (Plate XXXII, fig. 20).

Valvis lanceolatis, attenuatis, cum polis obtusis et rotundatis, 0·04–0·046 mm. longis, 0·006 mm. latis. Striae parallelae, 22–24 in 10 mikron. Area axillaris angusta, linearis. E grege *N. Schmidtii* Lag. 1.

Navicula cuspidata Kütz

Length, 0·074 mm., breadth, 0·018 mm. Striae, 18 in 0·01 mm. 3.

Navicula cuspidata var. **ambigua** Ehrenb.

Length, 0·059 mm., breadth, 0·03 mm. Striae, 20 in 0·01 mm. 3.

Navicula Perrotettii Grun. forma **ceylonica** forma nova. (Plate XXXIII, fig. 1).

Valvis rhombicis, lanceolatis, 0·115–0·119 mm. longis, 0·032 mm. latis. Striae, transverse 17–18 in 10 mikron cum 3 striis longitudinalis per totam valvae signatis. 3.

Stauroneis anceps Ehrenb. var. **amphicephala** Kütz. (Plate XXXII, fig. 21).

Length, 0·051 to 0·052 mm., breadth, 0·012 mm. Striae, 22 to 25 in 0·01 mm. 3.

Stauroneis Phoenicenteron Ehrenb. var. **gracilis** (Ehrenb.)

Length, 0·187 mm., breadth, 0·03 mm. Striae, 17 in 0·01 mm. 5.

Stauroneis Phoenicenteron Ehrenb. var. **vulgaris** Dipp. forma **intermedia** β and √ Dippel. (Plate XXXII, fig. 30). (√ Dippel).

Length, 0·049 to 0·073 mm., breadth, 0·012 to 0·02 mm. Striae, 18 to 25 in 0·01 mm. 5.

Stauroneis Phoenicenteron var. **ceylonica** var. nov. (Plate XXXII, fig. 29).

Length, 0·064 mm., breadth, 0·017 to 0·0187 mm. Striae, 18 to 20 in 0·01 mm. 3.

Pinnularia acrosphaera Bréb.

Length, 0·054 mm., breadth, 0·01 mm. Striae, 15 in 0·01 mm. 3.

Pinnularia divergens W. Smith var. **genuina** A. Mayer forma **ceylonica** forma nova. (Plate XXXIII, fig. 2).

Valvis lateribus leniter undulatis, 0·093–0·095 mm. longis, 0·015–0·017 mm. latis. Striae, 11 in 10 mikron. 3.

Pinnularia subcapitata Greg.

Length, 0·034 mm., breadth, 0·0068 mm. Striae, 15 in 0·01 mm. 3.

Pinnularia subcapitata var. **ceylonica** var. nov. (Plate XXXIII, fig. 3).

Valvis abbreviatis, tumidis cum polis arcuatis, 0·03–0·08 mm. longis, 0·006–0·007 mm. latis. Striae, 18 in 10 mikron. Medio valvae vitta transversa nuda interruptis. Area centralis obliqua transversa dilatata. 1.

Pinnularia legumen Ehrenb.

Length, 0·096 to 0·111 mm., breadth, 0·012 to 0·013 mm. Striae, 12 in 0·01 mm. 2.

Pinnularia legumen var. **florentina** Grun.

Length, 0·072 to 0·144 mm., breadth, 0·011 to 0·017 mm. Striae, 8 to 12 in 0·01 mm. 2, 3, 5.

Pinnularia microstauron (Ehrenb.)α. **eu–microstauron** A. Mayer var. **capitata** A. Mayer forma **ceylonica** forma nova. (Plate XXXIII, fig. 5).

Valvis tumidis, 0·064–0·08 mm. longis, 0·012–0·018 mm. latis. Striae, 11–12 in 10 mikron. 3.

Pinnularia microstauron β. **Brebissonii** (Kütz.) A. Mayer var. **ceylonica** var. nov. (Plate XXXIII, fig. 4).

Valvis leniter impressis, polis attenuatis et rotundatis 0·04–0·043 mm. longis, 0·085 mm. latis. Striae, 12 in 10 mikron, medio valvae vitta transversa nuda interrupta. 3.

Pinnularia microstauron β. **Brebissonii** var. **recta** var. nov. (Plate XXXIII, fig. 6).

Valvis elongatis ad marginem parallelis, ad polos attenuatis et rotundatis, 0·064–0·068 mm. longis, 0·008–0·012 mm. latis. Striis subradiantes 9–10 in 10 mikron, medio valvae vitta transversa nuda interruptis. 2.

Pinnularia appendiculata Ag.

Length, 0·034 mm., breadth, 0·0085. 2.

Pinnularia mayor Kütz. var. **linearis** Cleve.

Length, 0·122 to 0·18 mm., breadth, 0·018 to 0·025 mm. Striae, 7 to 9 in 0·01 mm. 2, 5.

Pinnularia interrupta W. Smith forma **stauroneiformis** Cleve.

Length, 0·054 to 0·056 mm., breadth, 0·0085 to 0·009. Striae, 11 to 14 in 0·01 mm. 2.

Pinnularia viridis Nitzsch. var. **intermedia** Cleve.

Length, 0·085 mm., breadth, 0·018 mm. Striae, 9 in 0·01 mm. 5.

Pinnularia cardinaliculus Cleve var. **ceylonica** var. nov. (Plate XXXIII, fig. 7).

Valvis 0·204–0·21 mm. longis, 0·03–0·035 mm. latis, cum polis obtusis rotundatis. Striae 7 in 10 mikron, medio valvae vitta transversa nuda interrupta. 5.

Gyrosigma Spenseri W. Smith.

Length, 0·111 mm., breadth, 0·014 mm. 3.

Frustulia vulgaris Thw. var. **asiatica** Skv. forma **ceylonica** forma nova. (Plate XXXIII, fig. 8).

Valvis ad marginem parallelis, 0·047–0·049 mm. longis, 0·0085–0·009 mm. latis, cum longitudinales striis ornatis. Habit. *F. vulgaris* var. *asiatica* was described from Hingan mountains of N. Manchuria (Philip. Jour. of Sc. vol. 55, 1. p. 44. Pl. 2. fig. 12).

Frustulia rhomboides Ehrenb.

Length, 0·064 mm., breadth, 0·0136. 5.

Frustulia ceylonica sp. nov. (Plate XXXIII, fig. 9).

Valvis elongatis lateribus undulatis, 3 gibbis, polis subrostratis, 0·044–0·046 mm. longis, 0·01–0·013 mm. latis. Striae ? 5.

Gomphonema lanceolatum Ehrenb.

Length, 0·0476 to 0·0816 mm., breadth, 0·0085 to 0·013 mm. Striae, 8 to 11 in 0·01 mm. 1, 2, 5.

Gomphonema gracile Ehrenb.

Length, 0·081 to 0·102 mm., breadth, 0·0102 to 0·014. Striae, 10 to 11 in 0·01 mm. 4.

Gomphonema intricatum Kütz. var. **Vibrio** Ehrenb.

Length, 0·073 mm., breadth, 0·01 mm. Striae, 17 in 0·01 mm. 5.

Gomphonema subtile Ehrenb. (Plate XXXIII, fig. 23).

Length, 0·049 mm., breadth, 0·0068 mm. Striae, 12 in 0·01 mm. 5.

Rhoicosphenia curvata (Kütz.) Grun.

Length, 0·044 mm., breadth, 0·009 mm. Striae, 9 in 0·01 mm. 5.

Cymbella ventricosa (Kütz.) Cleve var. **genuina** A. Mayer.

Length, 0·04 to 0·056 mm., breadth, 0·008 to 0·012 mm. Striae, 11 to 15 in 0·01 mm. 2, 4.

Cymbella ventricosa var. **laevis** (Naegeli) A. Mayer forma **maxima** forma nova. (Plate XXXIII, fig. 12).

Valvis 0·059–0·062 mm. longis, 0·014 mm. latis. Striae, 9 in 10 mikron. 2.

Cymbella ventricosa var. **caespitosa** (Kütz.) A Mayer.

Length, 0·023 mm., breadth, 0·0055 mm. Striae, 12 in 0·01 mm. 4.

Cymbella aequalis W. Smith var. **florentina** Grun. forma **ceylonica** forma nova. (Plate XXXIII, fig. 11.).

Valvis lanceolatis, 0·039–0·04 mm. longis, 0·0011 mm. latis. Striae, 9 in 10 mikron. The typical var. *florentina* has 15 striae in 10 mikron. 4.

Amphora acutiuscula Kütz.

Length, 0·04 mm., breadth, 0·006 mm. Striae, 18 in 0·01 mm. 1.

Amphora turgida Greg. var. **ceylonica** var. nov. (Plate XXXIII, fig. 10).

Valvis tumidis, ventre directis, dorso convexis, cum polis subrostratis, 0·022–0·03 mm. longis, 0·005–0·0068 mm. latis. Striae, 18–20 in 10 mikron. The typical *A turgida* is a marine diatom, known from Scotland, Norway, Red Sea, Java and Labuan. 1.

Amphora Nornani Rabenh.

Length, 0·0238 mm., breadth, 0·004 mm. Striae, 14 to 15 in 0·01 mm. 2.

Rhopalodia ventricosa (Grun.) O. Müll.

Length, 0·068 mm., breadth, 0·025 mm. 1.

Rhopalodia gibberula (Ehrenb.) O. Müll. var. **Van Heurckii** O. Müll. (Plate XXXIII, figs. 13, 14, 15).

Length, 0·032 mm., breadth, 0·009 to 0·01 mm. 1, 5.

Rhopalodia gibberula var. **protracta** Grun.

Length, 0·062 mm., breadth, 0·0085 mm. 5.

Nitzschia communis Rabenh.

Length, 0·051 mm., breadth, 0·006 mm. Striae, 11 in 0·01 mm. 3.

Hantzschia amphioxys (Kütz.) Grun. var. **vivax** Hantzsch.

Length, 0·059 to 0·074 mm., breadth, 0·008 to 0·01 mm. Striae, 8 to 9 in 0·01 mm. 3.

Stenopterobia intermedia Lewis. (Plate XXXIII, fig. 16).

Length, 0·097 mm., breadth, 0·005 mm. 5.

Surirella Alstonii sp. nov.[1] (Plate XXXIII, fig. 18).

Valvis minuta, 0·03 mm. longis, 0·011–0·012 mm. latis, elongato-ovalis. Costae 5–6 in 10 mikron, ad marginem arcuato confluentes, usque ad pseudorhaphem elevatum. 2.

1. Dedicavi hanc species Mr. A. H. G. Alston, Peradeniya, Ceylon.

Surirella tenera Greg.

Length, 0·056 mm., breadth, 0·012 mm. 2.

Surirella splendida (Ehrenb.) Kütz.

Length, 0·098 to 0·124 mm., breadth, 0·03 to 0·04. Costae, 2 to 3 in 10 mikron. 2, 3.

Surirella ceylonica sp. nov. (Plate XXXIII, figs. 19, 21, 22).

Valvis elongatis, parte anteriore rotundatis, parte posteriore attenuatis et rotundatis, 0·096–0·127 mm. longis, 0·03–0·034 mm. latis. Costae, 2–3 in 10 mikron, punctatis. E grege *Surirella rudis* Hustedt, A.S. Atlas Diat. Taf. 356. figs. 5, 6.

Cymatopleura Solea (Bréb). W. Smith. (Plate XXXIII, fig. 20).

Length, 0·085 mm., breadth, 0·014 mm. Striae, 16 to 18 in 0·01 mm. 1.

EXPLANATION OF PLATES

Plate XXXII.

Fig. 1.	*Melosira undulata* Kütz.
Figs. 2, 3, 5.	*Cerataulus thermalis* (Menegh.) Ralfs
Figs. 4, 6, 7.	*Cerataulus thermalis* var. *sinensis* (Grun.) Forti forma *ceylonica* forma nova.
Figs. 8, 9.	*Eunotia formica* Ehrenb. var. *ceylonica* var. nov.
Figs. 10, 11, 12.	*Eunotia ceylonica* sp. nov.
Fig. 13.	*Eunotia ceylonica* var. *bigibba* var. nov.
Fig. 14.	*Eunotia Frickei* Hustedt var. *ceylonica* var. nov.
Fig. 15.	*Eunotia Alstonii* sp. nov.
Fig. 16.	*Navicula oblonga* Kütz. var. *acuminata* Grun.
Fig. 17.	*Navicula oblonga* var. *subparallela* Rattray forma
Fig. 18.	*Navicula amphibola* Cleve.
Fig. 19.	*Navicula subtilissima* Cleve forma *baikalensis* Skv.and Meyer
Fig. 20.	*Navicula ceylonica* sp. nov.
Fig. 21.	*Stauroneis anceps* Ehrenb. var. *amphicephala* Kütz.
Figs. 22, 23.	*Terpsinoe musica* Ehrenb.
Fig. 24.	*Neidium affine* Ehrenb. var. *genuina* Cleve forma *ceylonica* forma nova.
Fig. 25.	*Navicula pelliculosa* (Bréb.) Hilse var. *ceylonica* var. nov.
Fig. 26.	*Neidium Kozlowi* var. *baikalensis* Skv. and Meyer. forma.
Fig. 27.	*Neidium Kozlowi* var. *baikalensis* Skv. and Meyer forma.
Fig. 28.	*Navicula digito–radiata* Greg. forma *ceylonica* forma nova.
Fig. 29.	*Stauroneis Phoenicenteron* Ehrenb. var. *ceylonica* var. nov.
Fig. 30.	*Stauroneis Phoenicenteron* var. *vulgaris* Dipp. forma *inter–media* V Dipp.

Plate XXXIII.

Fig. 1.	*Navicula Perrotettii* Grun. forma *ceylonica* forma nova.
Fig. 2.	*Pinnularia divergens* W. Smith var. *genuina* A. Mayer forma *ceylonica* forma nova.
Fig. 3.	*Pinnularia subcapitata* Greg var. *ceylonica* var. nov.
Fig. 4.	*Pinnularia microstauron* (Ehrenb.) Cleve B. *Brebissonii* (Kütz.) A. Mayer var. *ceylonica* var. nov.

Fig. 5. *Pinnularia microstauron* α *eu-microstauron* A. Mayer var. *capitata* A. Mayer forma *ceylonica* forma nova.

Fig. 6. *Pinnularia microstauron* β. *Brebissonii* var. *recta* var. nov.

Fig. 7. *Pinnularia cardinaliculus* Cleve var. *ceylonica* var. nov.

Fig. 8. *Frustulia vulgaris* Thw. var. *asiatica* Skv. forma *ceylonica* forma nova.

Fig. 9. *Frustulia ceylonica* sp. nov.

Fig. 10. *Amphora turgida* Greg. var. *ceylonica* var. nov.

Fig. 11. *Cymbella aequalis* W. Smith var. *florentina* Grun. forma *ceylonica* forma nova.

Fig. 12. *Cymbella ventricosa* (Kütz.) Cleve var. *laevis* (Naegeli) A. Mayer forma *maxima* forma nova.

Figs. 13, 14, 15. *Rhopalodia gibberula* (Ehrenb.) O. Müll. var. *Van Heurckii* O. Müll.

Fig. 16. *Stenopterobia intermedia* Lewis.

Fig. 17. *Achnanthidium lanceolatum* Bréb.

Fig. 18. *Surirella Alstonii* sp. nov.

Figs. 19, 21, 22. *Surirella ceylonica* sp. nov.

Fig. 20. *Cymatopleura Solea* (Bréb.) W. Smith.

Fig. 23. *Gomphonema subtilis* Ehrenb.

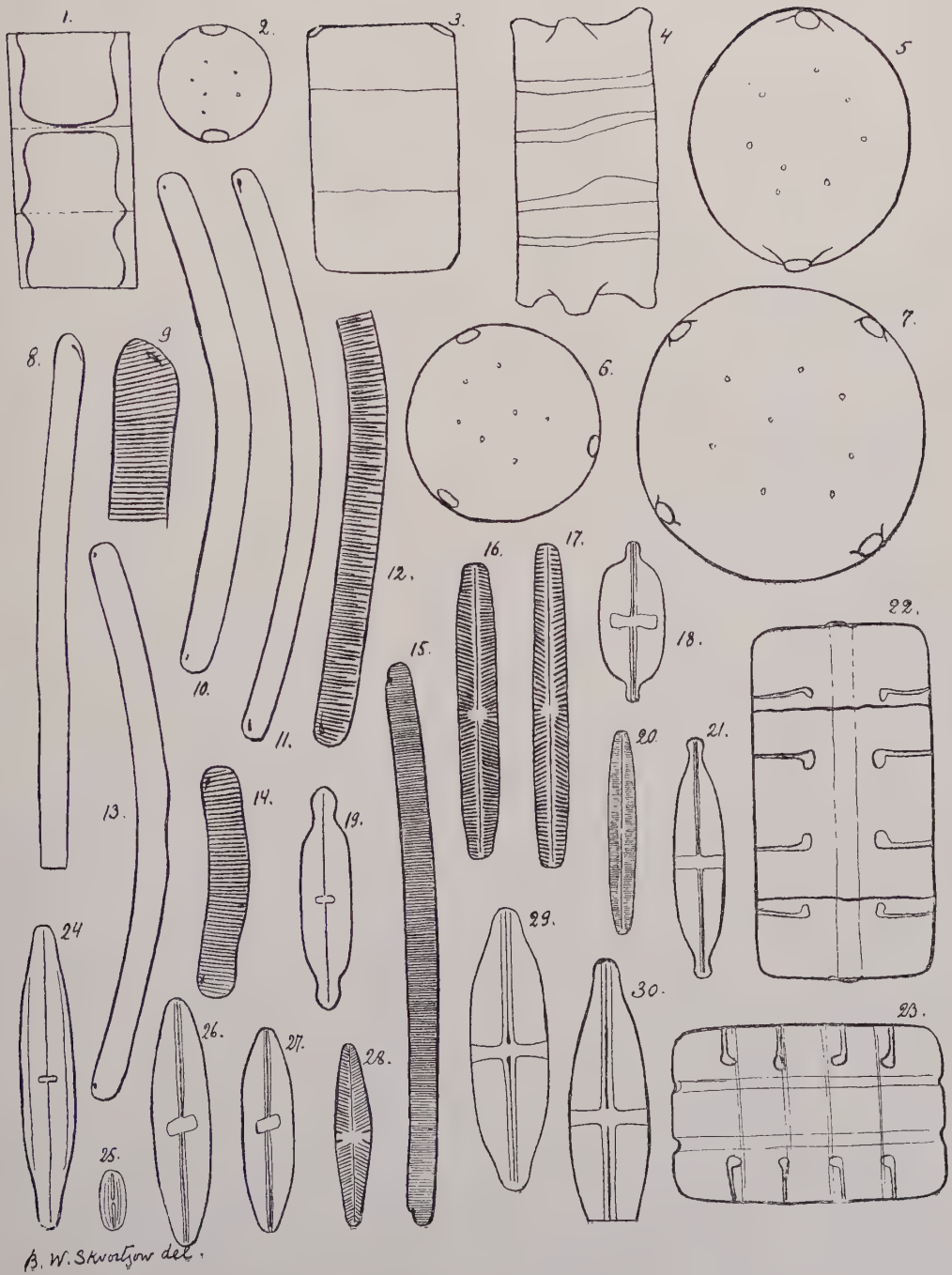
Plate XXXIV.

Figs. 1, 2, 4, 5, 6. *Cerataulus thermalis* (Menegh.) Ralfs var. *sinensis* (Grun.) Forti forma *ceylonica* forma nova.

Fig. 3. *Cerataulus thermalis* (Menegh.) Ralfs.

Fig. 7. *Terpsinoe musica* Ehrenb.

(Received for publication 11th April, 1929.)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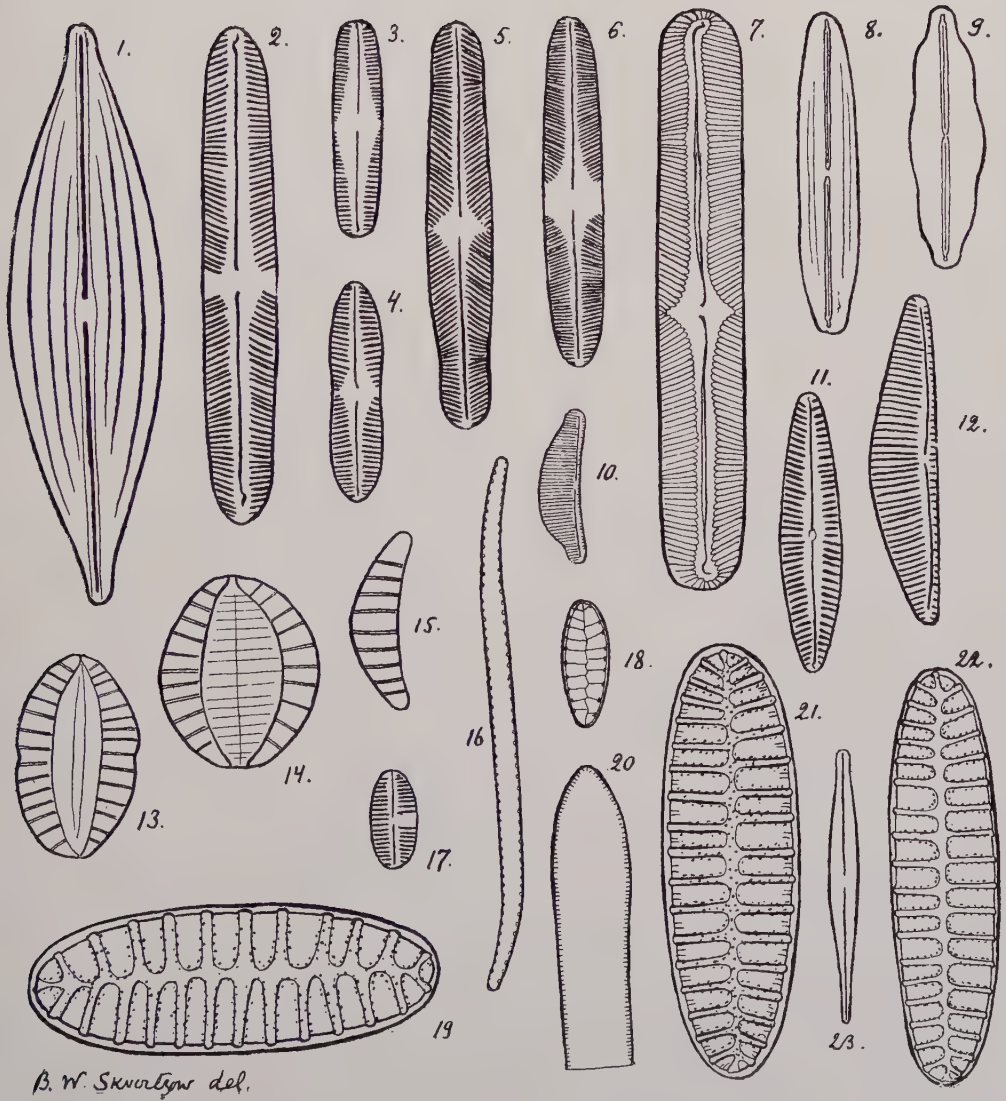
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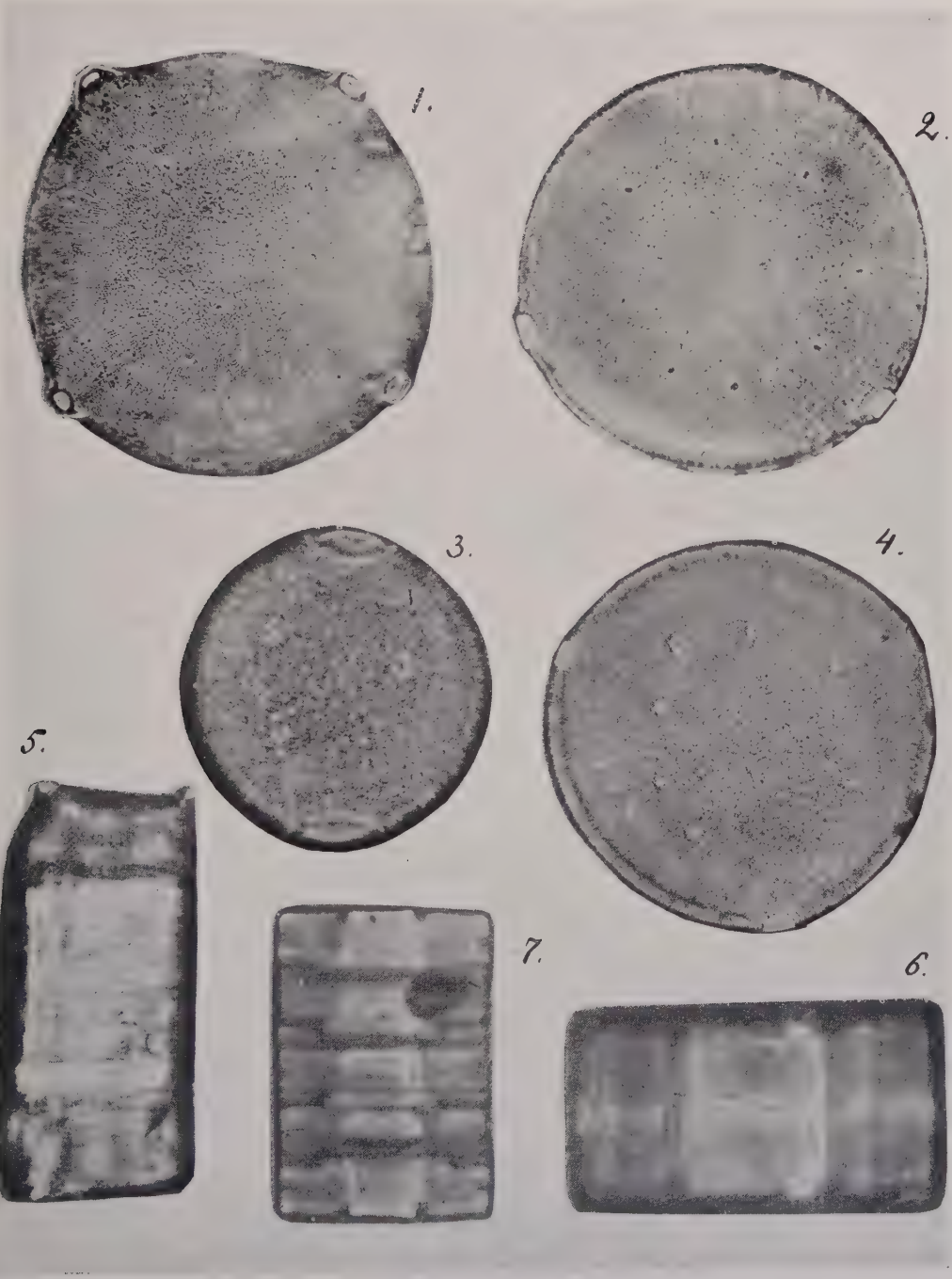
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The Preliminary Testing of Pure Line Selections of Rice (Cont.) Part III

BY

L. Lord, M.A.

Economic Botanist, Ceylon

Parts 1 and II of this paper, which appeared in the last number of these *Annals*, described the use of the so–called rod–row plot in the preliminary testing of rice selections. The reason for using such small plots is that only small amounts of seed are necessary and that, therefore, the testing and the subsequent discarding of unwanted selections can be carried out at an earlier stage than would be possible if larger–sized plots were used. Part II of this paper presented some evidence as to the justification of assuming that the yields of selections grown in rod–row plots are relatively similar to the yields of the same selections grown in larger plots which simulate more closely actual field conditions.

There is, of course, no object in carrying out rod–row tests if the results of such tests do not substantially agree with the results of tests in field plots. In the *Yala* (South–West) season of 1928 further evidence has been obtained as to the usefulness of preliminary testing in rod–row plots.

In Table II of Part II of this paper the 1927 yields of ten rices were given as yields per 100 plants for comparison with 1926 yields per 100 plants. It was shown, however, as a result of later work, that it is more accurate to use total yields of rod–row plots.

The 1927 total yields of above ten rices are now given in Table I.

TABLE I

Total yields of the inner 3 rows of rod-row plots of 1 and 2 CPY selections, Yala Season, 1927

Selection.	*Yield in lbs. Mean of 10 plots.*	*Yield expressed as a percentage of the control.*
1 CPY 5	2·59	133
1 CPY 15	2·46	126
1 CPY 16	2·43	125
1 CPY 3	2·37	121
1 CPY 17	2·21	113
1 CPY 19	2·20	113
1 CPY 18	1·99	102
Control (Hinati)	1·95	100
1 CPY 6	1·92	98
2 CPY 16	1·67	86

The standard error of the mean difference between two selections is 0·1435 lbs. or 6·58% which is slightly smaller than the standard error of the mean when yields per 100 plants are used. (See Part II, Table I). After the results of these 1927 tests had been worked out it was decided to discontinue testing most of the selections, partly owing to lack of space and mainly owing to most of the selections being awned. Other things being equal it is preferable to confine selection work to unawned rices as normally these give a larger percentage of white rice and are easier to handle. 1 CPY 15, which has short awns and the unawned 1 CPY 19, were retained for further testing in field plots during the *Yala* season of 1928. The remaining selections were discarded.

It will be seen that the 1927 tests show that 1 CPY 15 yielded 26% more than the control. This difference is very definitely significant. On the other hand, 1 CPY 15 yielded only 13% more than 1 CPY 19—a difference which here is nearly, but not quite, significant. The 13% increase of 1 CPY 19 over the control is also not quite significant.

In 1928 these two selections along with an older selection, Hk. 13, were tested against the same control paddy, *Hinati*. The plots used were 8·6′ wide by 35′ long and before harvest an outside border of 1′ was harvested separately and discarded. The area of the inside portion of the plot was 1/200 ac. The plots of each replication were laid down at random in compact blocks and there were seven replications. It may be said that a plot of only 1/200 ac. is too small to give results comparable with true field conditions, but it is believed that with the presence of a border and with systematic replications (as opposed to the random arrangement within each replication) the only disadvantage of 1/200 ac. plots is that their normal variation may be larger than that of larger plots. In Ceylon, where rice fields are so frequently very small, it would appear to be more accurate to use small plots and have one replication complete within one bunded field than to use large plots and have one replication taking up two or more fields. Any reduction of the normal variation due to increasing the number of plants per plot might easily be more than counterbalanced by the increase of the variation due to local differences in soil fertility. Where, however, conditions are such that complete replications of larger plots—*e.g.* 1/80 ac.—can each be accommodated in one field, the use of these larger plots is preferable.

Tables II and III give the yields of grain and straw for all plots, and Tables IV and V the analyses of variance.

TABLE II

Yield of Grain in lbs.

Selection or Variety.	*Replications.* a	b	c	d	e	f	g	*Total.*	*Mean.*	*Yield as a % of Control.*
1 CPY 19 ..	9·37	9·41	8·41	8·48	10·67	10·19	8·73	65·26	9·323	109·38
1 CPY 15 ..	10·23	13·37	9·37	10·42	11·05	11·45	10·14	76·03	10·861	127·43
Hk. 13 ..	4·91	6·75	4·73	6·37	6·12	4·16	4·81	37·85	5·407	63·44
Control (Hinati) ..	8·20	8·59	8·42	7·94	8·98	9·03	8·50	59·66	8·523	100·00
Total ..	32·71	38·12	30·93	33·21	36·82	34·83	32·18	238·80	8·52857	

TABLE III

Yield of Straw in lbs.

Selection or Variety.	*Replications.* a	b	c	d	e	f	g	*Total.*	*Mean.*	*Yield as a % of Control.*
1 CPY 19 ..	11·50	13·50	11·50	12·25	13·25	11·75	12·50	86·25	12·321	94·27
1 CPY 15 ..	13·25	18·75	11·75	12·62	14·75	13·50	12·75	97·37	13·910	106·43
Hk. 13 ..	8·75	11·00	7·62	12·12	8·50	6·62	10·25	64·86	9·266	70·89
Control (Hinati) ..	12·50	15·00	11·37	11·00	15·00	12·25	14·37	91·49	13·070	100·00
Total ..	46·00	58·25	42·24	47·99	51·50	44·12	49·87	339·97	12·1418	

TABLE IV

Analysis of Variance, Grain

Variance due to.	*Degrees of Freedom.*	*Sum of Squares.*	*Mean Square.*	*S.D.*	*Log S.D* ϵ
Blocks	6	10·1389			
Varieties	3	110·7167	36·905	6·07	1·8034
Experimental Error	18	11·1280	0·618	0·79	$\bar{1}$·6305
Total	27	131·9836		z =	3·4339

TABLE V

Analysis of Variance, Straw

Variance due to.	*Degrees of Freedom.*	*Sum of Squares.*	*Mean Square.*	*S.D.*	*Log S.D* ϵ
Blocks	6	42·6976			
Varieties	3	86·0456	28·68	5·35	1·6771
Experimental Error	18	33·6729	1·87	1·37	0·3148
Total	27	162·4161		z =	1·3623

The standard error of the differences between two means are, for grain 4·9%, and for straw 6·0%. For both grain and straw the z test is significant. It is interesting to note that the elimination of the variances due to local differences (which is rendered possible by laying down the plots of each replication at random within a compact block) has resulted in a small but appreciable decrease in the residual variance (*i.e.* the variance which is ascribable to the experimental error).

Table VI shows the analysis of variance for grain when the block or positional variance is not eliminated.

TABLE VI

Analysis of Variance, Grain

(Without elimination of positional variance)

Variance due to.	*Degrees of Freedom.*	*Sum of Squares.*	*Mean Square.*	*S.D.*	*S.D. with positional variance eliminated (See Table IV)*
Varieties	3	110·7167			
Experimental Error	24	21·2669	0·882	0·94 (=11·04 %)	0·79 (=9·26%)
Total	27	131·9836			

The effect of the elimination of the positional variance with straw is greater still and would imply that differences of fertility have relatively more effect on straw than on grain yields.

An examination of the grain yields shows that 1 CPY 15 has yielded 27·4% more than the control and 16% more than 1 CPY 19. Both these increases are significant. (The results of Hk. 13 are not germane to this paper).

The relative yields of 1 CPY 15 and 1 CPY 19 with the control are in 1928, 127·43 and 109·38 ; in 1927 they were 126 and 113. This is exceptionally close agreement and is further proof of the usefulness of preliminary testing in rod–row plots. 1 CPY 19 has yielded more than the control, but the increase is again hardly significant. The only difference between the 1927 and 1928 results is that in 1928 the increased yield of 1 CPY 15 over 1 CPY 19 is signficant, whereas in 1927 it was not. Two conjectures may be submitted to account for this, (a) the obvious one that the difference between 1 CPY 15 and 1 CPY 19 in 1927 was a true difference although the experiment was not sufficiently accurate to discover it, or (b) that some selections yield rather better in rod–row plots than in field plots. The second conjecture may be considered further. The essential differences between field plots and rod–row plots are (i) that in the former three seedlings are transplanted per hill[1] according

1 Hill is used here and is commonly used elsewhere to mean the place in the field where one seedling is planted alone or where two or more seedlings are transplanted together in a bunch. "Hill" is not the ideal term as it implies that the seedlings are transplanted on a mound of earth, whereas, of course, the fields are a level sheet of soft mud.

to the local method of transplanting, whereas in the latter, owing to the small number of plants available at the time rod–row plots are used, one seedling only is planted per hill, and (ii) that the distance between hills in rod–row plots is measured and is as near as possible 6″ ; in field plots the distance between hills is not measured but is approximately 6″–8.″

The object of transplanting three seedlings per hill is to reduce damage by land crabs.

Where effective control measures can be taken against land crabs and where conditions of fertility are normal it is not thought that the results of tests in rod–row plots will be at all misleading. As it is possible that transplanting three seedlings per hill in rod–row plots may increase their accuracy this will be tried, but it must be remembered that the use of three plants per hill will reduce the number of replications possible. It has been noticed that where fields are very poor in fertility transplanted seedlings take a longer time to recover from the shock of transplanting and never produce the normal number of tillers. Under such conditions the planting of three seedlings per hill is advisable.

SUMMARY

Part III of this paper gives the results of rice selections tested both in rod–row plots and field plots which provide further evidence that the use of rod–row plots for preliminary testing of rice selections is justifiable.

Campbellia cytinoides Wight

BY

T. Petch, B.A., B.Sc.

In the Annals of Botany, XXXVIII, pp. 679–698 (1924), I presented evidence to prove that the Ceylon plant, *Christisonia albida* Thw., given by Willis in " Age and Area " as an example of a plant which was known to have disappeared, was identical with *Campbellia aurantiaca* Wight, which occurs in Ceylon periodically in large quantities. That paper was intended as a preliminary to a re-investigation of the Ceylon species of *Christisonia* and *Campbellia*, but, owing to the difficulty of obtaining fresh specimens of some species, the enquiry was not sufficiently advanced to warrant publication when I relinquished the post of Government Botanist and Mycologist (Ceylon) in 1925. The ordinary methods of pressing and drying fail to preserve these plants adequately, and it is almost impossible to describe them accurately from dried herbarium specimens.

In the course of the paper referred to above, I stated that both the genus *Christisonia* and the genus *Campbellia* should be divided into two genera. The subject has since been taken up by Livera, who, working with the herbarium material and paintings at Peradeniya, and the published descriptions, has, *inter alia*, divided each of these genera into two—*Christisonia* into *Christisonia* and *Cliffordia*, and *Campbellia* into *Campbellia* and *Legocia*. (Livera, E. J. Aeginetiaceae : A new natural family of flowering plants. Ann. Roy. Bot. Gard., Peradeniya, X, pp. 145–159, 1927), *Campbellia aurantiaca* Wight now becomes *Legocia aurantiaca* (Wt.) Liv., *Campbellia cytinoides* being left in the old genus.

Recently I have been able to examine a large number of fresh specimens of *Campbellia cytinoides*, which is not uncommon in the jungle round Nuwara Eliya, Ceylon, at an elevation of 6,200 ft.

Livera gives the following table to show the differences between the two Ceylon species formerly included in the genus *Campbellia*.

	C. cytinoides.	*C. aurantiaca.*
Corolla upper (lip)	4 large	4 large
lower (lip)	1 small	1 small
Anthers	free, not didynamous	Free, didynamous
Anther cells	One	One
Dehiscence	Porous	Longitudinal
Spur.	None	Outgrowth of connective.
Ovary	One-locular at apex, two-locular at base.	Two-locular.

To show the shape of the corolla of *Campbellia cytinoides*, I give photographs of fresh flowers, detached from the inflorescence, but in their natural position. The two posterior petals form a standard ; the cleft between these two petals is short, and in bud the adjacent edges are rolled over one another, producing a beak at the apex of the closed corolla. Frequently, these two edges do not unroll when the flower expands, and the upper edge of the standard is then cuspidate. The lateral petals form, as will be seen, two wings, extended almost perpendicularly to the standard and deeply divided from the latter. The lower petal, smaller than the others, is curved outwards and downwards.

I am unable to see the division of the corolla into an upper lip of four large petals and a lower lip of one small petal. If a division is to be made, it should be two upper and three lower. Livera gives the corolla of *Christisonia* and *Cliffordia* as two upper petals and three lower, in contrast to *Campbellia* and *Legocia* which he considers have four upper and one lower. But, though I have examined dozens of *Christisonia bicolor*, *Ch. tricolor*, *Campbellia aurantiaca*, and *Camp. cytinoides*, I am unable to see any difference between them as regards this character.

The anthers of both *Campbellia cytinoides* and *Campbellia aurantiaca* are free, but the former open by a terminal pore, while the latter dehisce longitudinally, as stated in my previous paper.

In *Campbellia aurantiaca* the stamens are clearly didynamous. In *Campbellia cytinoides*, the four anthers may attain the same level, or either the anterior or the posterior pair may be slightly the higher, but the free part of the filaments of the posterior pair is about 3 mm. shorter than that of the filaments of the anterior pair. Consequently, if " didynamous " means having two stamens longer than the others, the stamens of *Campbellia cytinoides* are didynamous. In dissecting herbarium specimens this may be overlooked, because the traces of the filaments of the posterior stamens on the corolla descend almost to the level of the points of attachment of the anterior stamens, and, as the

corolla is membranous when dried, one is very liable to dissect out the stamen trace from it, in which case all the filaments will appear to be about the same length.

In *Campbellia aurantiaca*, the posterior anthers are spurred, while the anterior are either spurred or are furnished with rounded laterally flattened lobes, the appendages being outgrowths of the connective. Livera follows Trimen in stating that the anthers of *Campbellia cytinoides* are not spurred. They have, however, a semicircular vertical projection, an outgrowth of the connective, clearly evident on fresh specimens, similar to that on the anterior anthers of *Campbellia aurantiaca*. The difference between the two species, in this respect, is therefore one of degree only, and not of generic value.

In both *Campbellia aurantiaca* and *Campbellia cytinoides* the ovary is two-locular. Each cell contains two placentas, adnate to the septum, the stout strands which bear the placentas arising from the base of the ovary, separating to produce the placentas, and uniting again above to continue into the style. The placentation is axile. In the septum, between the two placentas, there is a vertical slit. At the time the corolla begins to fade, the two sides of this slit are in contact, but when the seeds are mature they are a little distance apart, so that there is a passage from one loculus of the ovary to the other.

There is no difference between the ovaries of *Campbellia aurantiaca* and *Camp. cytinoides*. If vertical sections of the ovary are taken in either species, it is readily seen that the septum is continuous below, round, and above the placentas.

Of the generic differences enumerated by Livera, only one is valid, viz., that the anthers of *C. cytinoides* open by a pore, while those of *C. aurantiaca* dehisce longitudinally.

Campbellia cytinoides is parasitic on the roots of *Strobilanthes*. In my experience, it is found, not among the denser growths of *Strobilanthes*, but where a few small trees break the continuity of the *Strobilanthes* colony and create a more open area containing a few scattered *Strobilanthes* plants. The parasite thus occurs in the less heavily shaded spots. As many as fifty inflorescences have been seen at one time on an area about six yards in diameter.

At the principal point of attachment of the parasite to its host plant, there is a globose gall about 5 mm. in diameter on the root of the host. On the top of this is another, larger, globose structure which is part of the parasite, and from the upper side of this there arises a short stout stem. From this stem and from the tuberous base of the parasite numerous stems arise, each of which, when it reaches the surface of the soil, produces an inflorescence. These stems are about 3 mm. diameter below,

and expand gradually, until they become about 1 cm. in diameter just beneath the inflorescence. They are very brittle, yellow, covered with brittle, rigid, hair–like outgrowths to within a short distance of the inflorescence, where they are clothed with imbricating bracts.

The main attachment to the host plant lies at about three to four inches below the surface. The stems, however, run obliquely to the surface and may be twelve inches long. Usually several flowering stems arise from the same tuberous attachment, together with numerous immature stems of varying length. Thus, several inflorescences appear together over an area of a few square feet, and the soil of that area is permeated by flowering and non–flowering stems. Apparently the plant is perennial, several stems coming to maturity each year. I have not observed branching of these stems (except occasionally a division into two inflorescences at the apex), nor have I seen on them the scars of previous inflorescences. It would seem that, after flowering, each stem dies down to the tuberous base.

The rigid hairs are potential haustoria. They are about two or three millimetres long, and half a millimetre in diameter. If one of these comes into contact with a *Strobilanthes* root, its tip swells and it becomes attached to and partly encircles the host root. Subsequently the whole haustorium swells and becomes spherical. But by far the greater number of the hairs do not find a host root, and those that do are usually merely adherent to fine rootlets and do not show a union comparable to that from which the stem arose.

Only the inflorescence appears above ground, where it forms a yellow sessile rosette. The inflorescence is racemose, with the flowers densely crowded. When, however, the stem divides into two just below the apex, one of the resulting inflorescences usually consists of a few flowers only, and in that case the flowers are rather widely separated and the inflorescence loose, recalling the Peradeniya Herbarium drawing of *Christisonia Thwaitesii*.

The individual flowers are pedicellate, with stout pedicels about $\frac{3}{4}$ inch long. Each arises from the axil of a scale–like, ovate, acute bract, and has two narrow, boat–shaped, acute bractlets, about $\frac{1}{4}$ to $\frac{3}{8}$ inch below the flower. In young bud, the flower is flattened dorsi–ventrally and enclosed in the two bractlets which give it a sharply–keeled edge.

The calyx is tubular–campanulate, plicate, with five, broadly triangular, acute teeth, and is glabrous externally.

The corolla is tubular below, infundibuliform above, five–lobed, with an oblique mouth. The two posterior lobes are shortly divided and form a standard, sometimes incurved and hooded. In bud, their adjacent margins form a beak, and sometimes they do not separate when

the flower expands, so that the upper edge of the standard is cuspidate. The two lateral lobes are slightly smaller than the posterior lobes, and more deeply divided from the latter. The anterior lobe is the smallest. When fresh the corolla is brittle, and unless they have been very carefully handled, herbarium specimens are apt to be defective. The corolla is hairy on the exterior at first, but becomes more or less glabrous with age.

The stamens, four in number, are didynamous. They all arise to about the same height, but the free parts of the filaments of the posterior pair are shorter than those of the anterior. The filaments are stout, and are furnished with a vertical semicircular "heel" at the apex. The anther is "one-celled," pyriform, directed obliquely downwards, and opens by a single pore at the tip.

The style is stout, curved outwards above, and terminates in an irregularly ovoid stigma, which has a slight lateral groove. The stigma is situated below the anthers, the pores of which turn towards it, so that the pollen can fall on the stigma.

The whole of the flower is yellow, with the exception of the stigma, which is white.

The ovary is globose, two-celled, with a slit in the septum between the placentas. The placentation is axile, with two placentas in each cell, adherent to the septum. The seeds have a loose testa, and among them are parenchymatous bodies similar to those which occur in *Campbellia aurantiaca*. There is no difference between the ovary of *Campbellia aurantiaca* and that of *Campbellia cytinoides*.

Specimens of *Campbellia cytinoides* were observed in bud on May 8th, 1927, but the outer flowers, the first to open, did not open until May 30th.

Other examples were found in bud on June 23rd, 1927. Two of these were carefully marked down. In both the latter, the outer flowers were open on July 2nd. One of them continued in flower until August 14th, and the other until August 21st. On September 4th, the ovaries of the outer flowers were not quite ripe; the seeds were fully formed, but the wall was still fleshy, and yellow internally. The duration of the inflorescence of *Campbellia cytinoides* is long.

In the Annals of Botany (*loc. cit.*) I suggested that some of these parasites of *Strobilanthes* only flowered at the time when the *Strobilanthes* flowered and died, as *Campbellia aurantiaca* Wight had been found in Ceylon only at such times. *Campbellia cytinoides*, however, flowers when the *Strobilanthes* does not show any sign of approaching flowering.

The data of Livera's paper appear to have been derived, as far as the Ceylon species are concerned, chiefly from the paintings in the Peradeniya Herbarium. In this connection, it has to be remembered that, although Eastern draughtsmen may excel at flower painting, they

are not, as a rule, rapid workers, and it is by no means uncommon for them to compound their drawing of a given species from two or three successive specimens, because the first had withered before the drawing was completed. On the other hand, if no second specimen is available, the drawing may be completed from an original rough sketch or from memory. There are thus several chances of error, and it is unsafe to rely too implicitly on paintings, especially if herbarium specimens are available.

Livera revives *Christisonia unicolor*, and transfers it to his new genus *Cliffordia*, as *Cliffordia unicolor* (Gardn.) Liv., comb. nov. The original specimen was collected in 1839 by Lear, who had a painting made from it. Gardner arrived in Ceylon in 1844, and described it ; he had no specimen, but described it from the painting only. Trimen considered that the painting was almost certainly meant to represent a *Campbellia*, and I agree with that interpretation. But it is impossible to say which species, as the centre of the flower in the painting is merely a confused white mass which does not show stamens or stigma distinctly. Hence *Christisonia unicolor* Gardn. must always remain indeterminable.

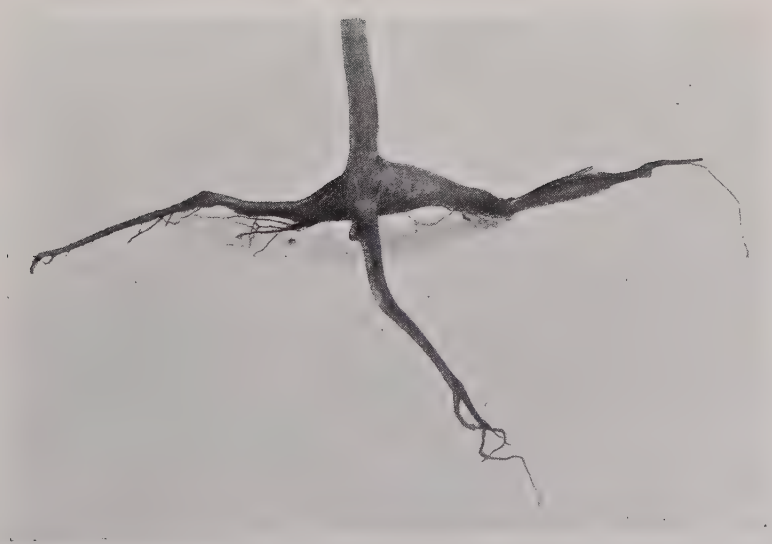
Livera describes *Cliffordia zeylanica* from a drawing and specimens which were included in the Peradeniya Herbarium under *Christisonia Thwaitesii*. These specimens were part of Thwaites C.P. 3929, and were found by me, part among the unmounted duplicates of C.P. 3929 in Herb. Peradeniya, and part in the Hakgala Herbarium, to which they had been transferred from the Peradeniya duplicates about the year 1900. As I have previously recorded (Ann. Bot., *loc. cit.*) the specimens are *Christisonia Thwaitesii*, *Campbellia aurantiaca*, and *Christisonia bicolor*. Livera has not marked any of these " *Cliffordia zeylanica*," but the only specimens which at all resemble the drawing are two inflorescences of *Campbellia aurantiaca*.

The corresponding painting is a puzzle. The figure of the entire inflorescence is *Campbellia aurantiaca* in everything but the stigma, while the accompanying drawing of the separate flower appears to be nearer *Christisonia Thwaitesii* in both stigma and anthers. I hazard the solution that the painting was begun from a specimen of *Campbellia aurantiaca* and completed from a specimen of *Christisonia Thwaitesii*. The description of *Cliffordia zeylanica* is based on this figure, and, on the available evidence, this species must be relegated to the same category as *Christisonia unicolor* Gardn.

Livera describes the roots of *Christisonia Thwaitesii* as coralloid, and those of *Cliffordia zeylanica* as wiry. There are no coralloid roots on the herbarium specimens of *Christisonia Thwaitesii*, and the stout root shown in the figure is that of the host or, more probably, some

neighbouring plant. The figure of "*Cliffordia zeylanica*" shows a fringe of fibrous roots arising all round the stem just above the point where the stem was broken off when the specimen was collected. These roots resemble the roots of a grass, and are quite unlike anything which occurs in *Campbellia* or *Christisonia* (in the old sense of these genera). They either have been based on some adhering foreign roots, or are imaginary.

Re-descriptions of both the Ceylon and Indian species of these genera, from fresh specimens, are required before any re-classification can be attempted. Specimens should also be preserved in alcohol, so that there may be no doubt about the adherence of the anthers, the shape of the stigma, the character of the spur, and other points which are hardly determinable on pressed specimens.



Buttress Roots

BY

T. Petch, B.A., B.Sc.

WITH FOUR PLATES

In view of the attention which is now being given to the problem of the occurrence and development of buttress roots in tropical trees, the following observations on buttress roots in Ceylon may perhaps prove of interest.

ASSOCIATION WITH HABITAT

Schimper stated that plank buttresses are a peculiarity of trees in a tropical climate with an abundant rainfall, and the prevailing opinion usually associates them with tropical rain forest. Yet, although they may be more general in such situations, they are not confined to them. Francis (Proc. Roy. Soc. Queensland, XXXVI, pp. 21–37) has described the buttress roots of Queensland trees in sub-tropical "rain forest," in which 57 inches is regarded as a "relatively high annual rainfall."

Bombax malabaricum, which in Ceylon is always buttressed, is stated by Gamble to prefer "the deciduous forests, but may be found in others in suitable places ; it is common in grass lands, and is conspicuous on hot hillsides." In Ceylon, it is usually found as a planted tree, but Trimen (MSS) regarded it as indigenous on the patanas (grass lands)on the Eastern side of the Island. It develops its buttresses even in the most open situations.

Poinciana regia, an introduced tree in Ceylon, is commonly planted in gardens or along roadsides. In open situations it usually does not grow to a great height, often not more than 30 feet high, but where protected when young by other trees it may attain a height of 60 feet. In the matter of buttresses it is variable. Some trees have buttresses 5 feet high at the bole, others have merely flanged roots, while others have neither. These differences are not associated with habitat in the general sense. Trees of approximately equal size at Peradeniya, grown under

apparently similar conditions, may be buttressed or not. Further, in *Poinciana regia* the form of the tree is not necessarily hereditary; a seedling from an old unbuttressed tree began to develop buttresses at the age of three years.

It would appear probable that a study of such a species as *Poinciana regia*, in which the development of buttresses is variable, might afford more information on the problem than that of a species which is always buttressed.

THE AGE AT WHICH BUTTRESSES DEVELOP

Whitford stated: "It will be seen that the same causes which operate to produce short thick boles in open places in temperate regions are possibly also present here, with the difference that the buttresses, which take the place and perform the function of uniformly thick trunks, appear later in the life of the tree. This means that the tree in youth, while it is crowded in the forest, develops a regular bole, but that when it reaches above the surrounding vegetation, in response to the increased heaviness of the top, the buttresses appear at the base, enabling the tree to withstand the extra strain."

Francis has pointed out that the foregoing view is not supported by the observations which have been made in Queensland, and states that the buttresses appear at a comparatively early stage of growth in a large number of rain-forest species. He cites examples of buttressed trees, varying in height from 26 to 33 feet, and in diameter from 2·25 to 3·5 inches.

The writer has observed the beginning of the buttress formation in *Poinciana regia* in the case of trees, 2–3 years old, 1·5 inches diameter at the base, and not exceeding 12 feet in total height. The base of one such tree which was cut down at the age of four years is shown in Text figure 1. The diameter of the stem above the buttresses was then 7 cm. The height of the buttress on the right was 14 cm., and that lateral root diminished to a diameter of 2 cm. at a distance of 90 cm. from the stem. The height of the buttress on the left was 12 cm., and that lateral root also diminished to a diameter of 2 cm. at a distance of 90 cm. The length of tap root photographed is 80 cm., at which depth it was 5 mm. in diameter. Just below the lateral roots, the tap root was slightly laterally compressed and measured 5 × 4 cm. in cross section; at a depth of 50 cm., where it was 3 cm. in diameter, it divided into three. The lateral roots of this tree ran north and south, along the line of an adjacent hedge.

THE CAUSES OF BUTTRESSES

One reason which has been assigned for the production of buttresses is that they are developed in response to strains caused by the wind. Whitford states: "So long as the tree top is protected on all sides by others, the strain will not be very great for two reasons, *i.e.*, the top will not have a chance to broaden out and it will not be exposed to strong winds, but so soon as it emerges above the tops of other trees, the exposure and the increasing heaviness above will produce a strain sufficiently great to cause a stimulus of growth at the base and thus produce the buttresses."

Reference has already been made to the age at which the buttresses begin to appear. In the case of *Poinciana regia* they may begin to develop on two-year old trees which are well protected from the wind by neighbouring tree belts, and before the head has branched appreciably.

If, however, buttresses developed in response to strains caused by the wind one might expect that, in a district where the direction of the prevailing winds was more or less constant, the buttresses would exhibit a tendency towards a uniform orientation. That, however, does not quite follow. Buttresses develop from lateral roots, and there might not be any lateral root in the line of the prevailing wind which could be developed into a buttress to meet the strain. The same consideration would appear to rule out the wind theory altogether, for the tree cannot develop buttresses except where the lateral roots are, and therefore cannot meet strains directly. It may, however, be argued that the strain is met indirectly by the development of two or more buttresses at an angle with the prevailing winds so that the force of the wind is met by the component strains on the buttresses, in which case it would again be probable that the buttresses would tend to a uniform orientation. There would not, for example, be any stimulus to the formation of buttresses running north and south in a district where the prevailing winds were east and west. But in general buttresses develop all round a tree, and as their position depends upon the position of the lateral roots it follows that it is purely fortuitous in space, *i.e.*, relatively to the points of the compass.

At Peradeniya, the prevailing winds, and certainly the strongest winds, are from the north–east and the south–west, and they blow from each of these quarters for several months at a time. In general, the wind is north–east from October to April, with strong winds in February, and south–west from May to September, with strong winds in June–July.

Near the eastern side of the Royal Botanic Gardens, Peradeniya, there is an old-established row of *Canarium commune*, part of which is shown on plate XXXV. This row runs north and south, curving round to the west at its northern end. It is not protected from the north–east

winds, and, although the main breadth of the gardens lies to the west of it, the trees are taller than any near at hand, so that they receive little protection on that side either. With the object of ascertaining whether the buttress roots of these trees showed any definite orientation, it was decided to map them out with the aid of a compass, but their directions were so various that the project was abandoned. Similarly, it has not been possible to detect any relation to the prevailing winds in the buttresses of other trees of numerous species at Peradeniya.

A notable feature in the buttress roots of this row of *Canarium commune* is that in many instances they do not run in a straight line from the bole of the tree. In some cases, after a distance of two or three feet, they curve round, almost at right angles, and may even make a second turn in the opposite direction. These turns are, no doubt, due to deviations of the original lateral root from a straight line. In one case, however, a slightly flanged root runs on from the curve, continuing the line of the lateral from the bole, while the buttress, three feet high, curves round almost at right angles, and, although verification is not now possible, this gives the impression that the buttress has developed from a primary lateral root for the first part of its length, and subsequently from a side branch of that root, or secondary lateral. In that case, it is perhaps justifiable to surmise that the development of the buttress has proceeded along the line of the strongest lateral root, and where a secondary lateral has become stronger than the primary, the line of development has been diverted from the latter to the former. But whether this is correct or not, the change in direction of the buttress would appear at variance with the view that buttresses are developed in response to strains caused by winds.

The buttresses of these *Canarium* trees commonly have lateral buttresses. Some roots, which have not formed buttresses at the stem, develop flanges, up to a foot high, 6 or 10 feet from the bole. The smallest, more or less suppressed, trees have the smallest and fewest buttresses.

As regards the possible stimulus to the formation of buttresses, arising from the weight of the crown, the following facts may be noted.

Bombax malabaricum, in Ceylon, commonly grows to a height of 100 feet and has a stout stem. Holtermann gives the height as 150 feet and the girth as 40 ft. It does not develop a large crown, partly because many of its branches die and fall off ; and its main branches are chiefly suberect. It is always buttressed, but in varying degree.

Poinciana regia, in Ceylon, does not as a rule, develop a large crown ; the head is usually loose and straggling. In one instance, an old tree in a bungalow garden at an elevation of 2,500 feet, was only about 20 feet

high, but it had buttresses 5 feet high at their junction with the bole, diminishing to 3 ft. in height at a distance of 4 ft. from it.

Plate XXXVII B shows the base of an old tree in the Botanic Gardens, Peradeniya. This was about 60 feet in height, much larger than the tree referred to in the foregoing paragraph, but its buttresses were smaller, about 3 feet high at the bole. The tree stood at the edge of the belt of trees which borders the flower garden and at this point runs north and south. It was completely protected from the south–west winds, but exposed on its eastern side, which faced the lawns of the flower garden. The buttresses seen in the photograph run more or less north and south, probably because, when the lateral roots developed, they ran along the shaded and damp edge of the shrubbery in preference to the open lawn. Similarly, the two laterals of the tree in Text figure 1 ran along a Panax hedge.

Plate XXXVIII A shows the base of another example of *Poinciana regia* at Peradeniya. This was rather taller than the tree in the Botanic Gardens illustrated in Plate XXXVII B. Its crown had an irregular spread, about 70 feet in diameter, and its weight was increased by a dense growth of *Philodendron* sp., evident in the photograph. The circumference of the stem at a height of 4 feet was 9 feet. This tree was fully exposed to both the north-east and the south-west winds. But it has no buttresses. The fluting of the stem appears more pronounced on the photograph than it was actually, because the photo–graph was taken early in the morning with the sun to the right of the tree.

The differences between these examples of *Poinciana regia* cannot be attributed to differences in the weight of the crown or differences of exposure to wind. The smallest tree of the three had the largest buttresses, while the largest and most exposed tree had no buttresses.

The tree in the Botanic Gardens died in consequence of the attack of *Fomes lucidus* at the base of the stem. Its tap root was decayed, but was insignificant. On the other hand, the tree shown in Plate XXXVIII A has a well–developed tap root, and though the tree has been felled, its stump, at ground level, is so large that it has not been dug out.

Referring again to the young tree, the base of which is shown in Text figure 1, it will be seen that the tap root is small, in comparison with the lateral roots.

Several similar cases of buttressed trees which lack tap roots have been observed. The trees of the well–known row of *Ficus elastica* on the front of the Botanic Gardens, Peradeniya, began to decay about the year 1907 and one of them was blown over in that year. A photograph of this tree is given on Plate XXXVII A, the mass of soil torn up by

the surface roots being evident on the right. There was, however, no sign of a tap root. The remaining trees of the row were subsequently felled, and in all cases it was found that the stem was hollow in the centre and no tap root was present. It is, of course, impossible to say at what stage of growth of the tree the tap root began to decay, but when full grown they simply sat on the ground as far as concerns the area covered by the stem and the proximal parts of the flanged lateral roots. Further out, these laterals were fixed by small secondary roots.

Large old trees of *Canarium zeylanicum* in the Henaratgoda Botanic Garden, which is in the low-country but has about the same rainfall as Peradeniya, had buttresses extending to a height of 12 feet. One of these was blown over, and was found to have no tap root.

A parallel condition has been noted by Francis in buttressed trees in Queensland. He states (p. 31): "In all instances of prominently buttressed mature trees, which have been examined by the writer, a decided diminution was observed in the size of the stem or axis of the trees from just above the buttresses towards its point of contact with the soil. The extent of this diminution was measured in a large stump of *Echinocarpus Woollsii*. The stem above the buttresses measured 2 feet in diameter, whilst its maximum diameter at the surface of the soil as the woody axis of the buttresses was only 9 inches, or three-eighths of its diameter above the buttresses. A similar tapering of the woody axis towards the surface of the soil was observed in large buttressed trees of *Cedrela toona* var. *australis*, *Tarrietia argyrodendron* var. *trifoliolata*, and *Weinmannia lachnocarpa*. It was also evident in a specimen of *Ceriops Candolleana*." It would appear to follow that in such cases the tap root of the tree is smaller than it would be if the bole of the tree (minus the buttresses) were of uniform diameter down to the base, or followed the more general course of expanding down to the base. In other words, the tap root, relatively to the dimensions of the tree, is inadequate.

The writer would put forward, as a working hypothesis, (1) that the presence of buttress roots is associated with a deficient tap root, and (2) that the formation of buttress roots is due to the restriction of the food and water currents to limited narrow regions of the stem continuous with the lateral roots.

The first supposition might explain why buttressed trees are the more prevalent in tropical rain forest, especially at low elevations, as a permanently water-logged soil might retard the formation of a tap root. The objection has been raised that this would require that all trees in that situation should have buttresses, but that does not follow, since the tap roots of some species might be able to endure those conditions.

The same supposition might also serve to explain the buttress habit in trees which, like the Bombax, are found on open hillsides. In such localities, in Ceylon at least, the soil is usually thin and has rock near the surface. In this connection, it may be noted that the unbuttressed Poinciana shown on Plate XXXVIII A was growing on deep alluvial soil. It must, however, be recorded that the young tree shown in Text figure 1 was growing on the same soil, at a distance of a few yards, being in fact a self-sown seedling from the unbuttressed tree, so that a deep soil does not necessarily ensure the development of a tap root and the absence of buttresses in *Poinciana regia*.

As regards the second supposition, it may be said that although it is generally agreed that a tree is not a physiological unit that fact is frequently overlooked, perhaps because in temperate climates the effect of climatic conditions makes it behave, in general, as though it were. In temperate countries, a tree, for example, will lose all its leaves in autumn at the same time, or should the leaf-fall on certain branches be delayed the whole tree nevertheless becomes leafless ultimately. On the other hand, in the tropics, or at least in those localities where all or some of the climatic conditions are uniform, the individuality of the different parts of a tree is very striking. It is quite common in the wet zone of Ceylon, where the annual variation of temperature is small, for one part of a tree to lose its leaves in "wintering," before the leaves on the remainder of the crown have begun to change colour ; and as the resting period is of short duration, the branches of that part may put out new leaves, before the old leaves on the other part have fallen. This frequently occurs in *Hevea brasiliensis*. There is consequently in such cases a difference in the physiological condition of the main branches of the crown at the time when leaf-fall begins, and the different sectors of the crown may behave as totally distinct trees.

Evidence regarding the individuality of the different regions of the internal tissues of the stem is not so immediately obvious. Two cases, however, have come under my notice, each the result of an accident and both concerning *Hevea brasiliensis*. In one case, a quantity of a strong disinfectant solution was poured down a drain, into which penetrated a main lateral of a *Hevea*. The root was killed, together with a strip of bark a few inches wide, extending from the lateral root, up the trunk of the tree, in a long spiral, following the direction of the wood fibres. The second case was similar, the tree being situated near a garage and its lateral root being killed by waste from that source ; in this instance, the strip of dead bark, about 4 inches wide, extended up the tree for a height of about 20 feet. In both cases the substance absorbed by the root killed the wood and bark in a narrow strip in continuation of the lateral root,

The foregoing instances indicate that the water, etc., absorbed by a given lateral root, is not necessarily contributed to a general stock available to all parts of the tree, but may be conducted along a definite region of limited breadth, and may perhaps ultimately supply only one main branch or group of branches.

In the case of a tree furnished with a well-developed tap root, the water, etc., absorbed by the tap root would be supplied to the whole stem, while that absorbed by the lateral roots would be superadded. If, on the other hand, the tap root were deficient or absent, the general supply to the whole stem would be reduced, and practically all the available water, etc., would be furnished by the laterals. As this (if the foregoing conclusion is correct) would be conducted along definite lines in continuation of the lateral roots, it is possible that the process would lead to an excessive growth along those lines, with the consequent formation of buttresses. It is not evident, however, why the buttresses should assume the plank form.

The photograph of *Canarium commune*, shown on Plate XXXVI, introduces apparently another phase of the problem under consideration. The lowest branch, on the left, has been cut off, but it will be seen that it was furnished with a " plank buttress " in the axil of the branch, and similar formations are present in the axils of the two branches above. This example is one of the trees of the row of Plate XXXV. It is not included in the latter photograph, but the trees shown there exhibit the same phenomenon. It would appear that any theory which explains the formation of buttress roots should also explain the occurrence of these buttressed branches.

Plate XXXVIII B shows the base of a *Terminalia Catappa*. This, though the buttresses are not large, is an interesting case. It has four buttresses (one on the other side of the tree), and two of these, those on the left, are not radial, but bend round, so that three are directed more or less to one side. This tree grew to the left of a large wild mango, which was felled before this photograph was taken, and its main stem penetrated among the mango branches. Consequently all branches on the right hand side of the *Terminalia* were suppressed, and its main stem terminated in a cluster of weak shoots which died back periodically. The tree was strictly one-sided, while on the left a large lateral branch extended over the road seen in the photograph to a distance of 50 feet from the bole, and sank at its extremity to within 6 feet of the ground. The main development of buttresses is on the opposite side of the tree to the large lateral branch, and two of the buttresses are curved round to that side, This at first sight appears to afford decided support for the theory that buttresses are developed to meet the strain caused by the weight of the

crown, but on further consideration it will be clear that the relative positions of the branch and the buttresses might equally be explained on the supposition that those particular lateral roots supply water, etc., to that branch.

The photographs in illustration of this paper were taken by Mr. L. S. Bertus, Assistant in Mycology, Department of Agriculture, Peradeniya.

EXPLANATION OF PLATES

Plate XXXV. *Canarium commune.* The highest buttresses on the two trees to the left descend to a path at a lower level than the grass in the foreground.

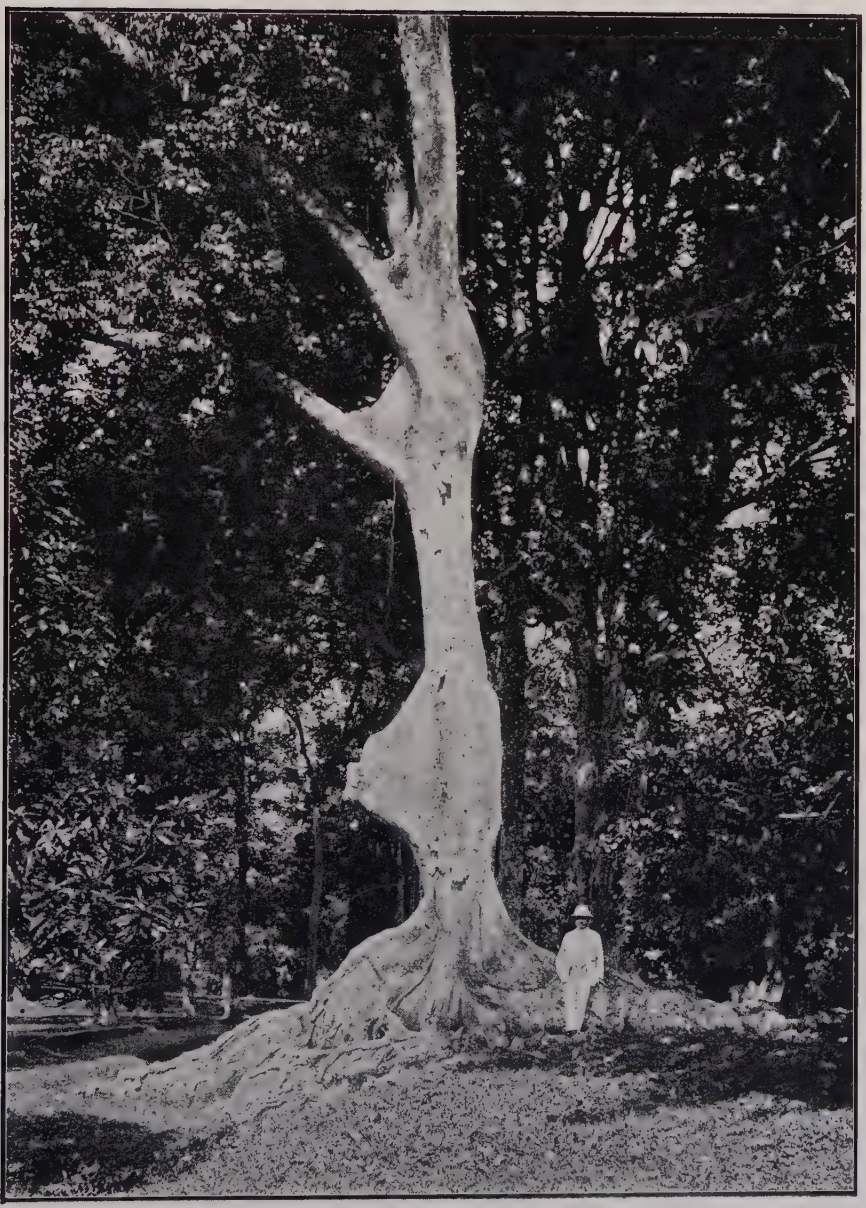
Plate XXXVI. *Canarium commune.* Example showing buttressed branches.

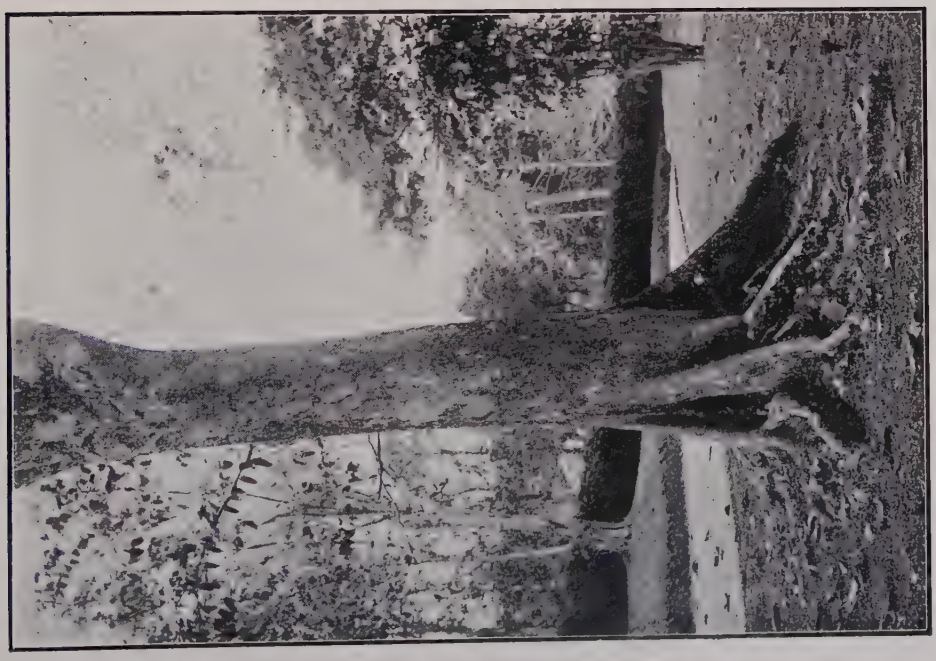
Plate XXXVIIA. A fallen *Ficus elastica.* Length about 100 feet.

Plate XXXVIIB. *Poinciana regia.*

Plate XXXVIIIA. *Poinciana regia.*

Plate XXXVIIIB. *Terminalia Catappa.*





The Botanical Identity of Tawenna and allied Timbers

BY

H. C. King, B.A. (Oxon)

Assistant Conservator of Forests, Southern Division (West), Galle

AND

A. H. G. Alston, B.A. (Oxon), F.L.S.

Systematic Botanist, Department of Agriculture, Peradeniya

WITH THREE PLATES

Towards the end of 1927 the possibilities of the genus Palaquium as a potential source of organised supplies of timber began to receive attention in the Galle District of the Southern Province and these notes are the result of enquiries into the botanical identity of the species involved. In the limited area under treatment by the Forest Department, three species which are relatively plentiful in the form of seedlings and saplings, are known to occur throughout the wetter districts of the Western and Sabaragamuwa Provinces also, and this early publication of data is designed to justify an extension of the work and to facilitate the recognition of species in the field and of the corresponding timbers.

There are about 65 species allotted to this genus, all Indo-Malayan : the most important is *Palaquium Gutta*, the source of the best commercial *Gutta Percha*. An inferior variety, which is principally exported from Borneo, is produced by *P. leiocarpum* ; *Payena Leerii* and *Palaquium Treubii* are also exploited. The gutta is obtained by felling wild trees or by extraction from the leaves of cultivated trees (1, 2). Latex exudes from the bark of certain of the species which are indigenous in Ceylon, and most freely from that of *Palaquium petiolare*, but the latex, after being tested at the Imperial Institute, was found to be of small economic value (3, 4).

THE GENUS IN CEYLON

In Ceylon the genus is represented by 7 species, all endemic, of which one is a reputable softwood, while one at least, yielding the *Tawenna*

timber of commerce, is a promising hardwood. In view of subsequent remarks on its distribution and silvicultural characteristics the genus appears to merit very marked attention in future schemes of development. *Isonandra lanceolata* is the single species of a genus closely allied to *Palaquium* and is included in the botanical and timber keys because its vernacular name and its timber are confused with those of the species of *Palaquium*.

The general uncertainty as to identification was due to three main causes (1) The incomplete information in the local Flora, Dr. Trimen's standard work, in which the vernacular names of this genus are given only in one case, while the timbers appropriate to each species are not described. (2) The utter confusion in the vernacular names for different species. While comparatively few plants have Sinhalese names it becomes increasingly difficult to find a villager who is familiar with the trees of this genus and these enquiries offer an opportunity of revising the vernacular names, which are in many cases allotted indiscriminately to two or more species. One alternative would be to prefix the name of the forest or the locality to the vernacular name thus Polhunnawa–molpedda, but apart from the length of such compound names, reference would be necessary to a key or index, and besides, forests of the same name occur in more than one district. The vernacular name given for each species in the key of timbers usually consists of the best local name with a distinguishing prefix, which, as far as possible, is descriptive of the timber. If forest officers will consistently use these revised names, they will later be adopted by the villagers in the districts where development is in progress. *Ratatiya* is one name invariably applied in two separate districts to *Palaquium Thwaitesii*, perhaps because this species is unique in having, with variations, the same form of leaf in the seedling stage and in the mature tree. (3) The striking dissimilarity between the mature leaf of several of the species and that of the juvenile form, also the remarkably variable forms presented by the same species.

The annexed botanical key, combined with timber specimens taken from the same trees, definitely establishes the types of timber which will be produced if certain species are propagated and should contribute to the development of these highly productive Wet Zone forests. Modern tendencies in such work are towards indigenous species rather than exotics and towards mixtures of several species in preference to pure plantations.

Grateful acknowledgment is due to Mr. F. Lewis for his notes and personal assistance ; also to Mr. S. D. J. E. Senaratna of the Department of Agriculture for the preparation of slides and photographs.

It would be satisfactory if a similar key of equal finality could be prepared for the identification of casual specimens of sawn timber apart from their appropriate leaves. The timbers of the genus have for years been the subject of ingenuous and other errors of identity, but their superficial as opposed to their microscopic characteristics cannot be tabulated decisively for identification with the naked eye or with a simple lens. The arrangement of vessels or "pores" in radial chains and the appearance of fine concentric rings of darkened tissue are features of the transverse section of all the timbers, but individual timbers appear to vary within wide limits and may be found to overlap with those of other species: specimens submitted for identification would normally consist of heartwood, whereas the distinguishing features are more conspicuous in the sapwood.

It is probable that in due course the timbers will be exported for exhaustive tests under the auspices of the Imperial Forestry Institute, and the result of such investigation, will be of scientific interest and may indicate the suitability of certain of the timbers for export for special purposes.

For the practical requirements of the local timber trade the timbers can be grouped in classes according to their known or estimated value for constructional and other work and the classes can, so far as is known from the present somewhat incomplete data, be distinguished from each other by the following key and by comparing the size of the vessels under a lens (magnifying power 5 times) with those of certified specimens. If slides can be prepared, identification with a microscope presents no difficulty.

The timbers can be arranged as follows in order of size of vessels :—

TABLE I

Timber.	*Utility.*	*Relative size, etc., of vessel.*	*Arrangement.*
Palaquium petiolare	Class 1	Largest	Singly or in short chains
Palaquium rubiginosum	„ 2	Second	do
Palaquium Thwaitesii	„ 3	Third	In chains up to 10 or more
Palaquium canaliculatum	„ 3	Third	
Palaquium grande	„ 3	Third but of varying sizes	
Palaquium grande var. *parvifolium*	„ 3	Third	
Palaquium laevifolium	„ 2	Very small	Singly or in short chains
Isonandra lanceolata	„ 2	do	do

The Distribution and Silviculture of the genus in the South and West of the Island require further investigation: as far as is known at present the species in the Galle District are grouped as shown in the annexed table II.

(*a*) The coastal forests, all of small extent, which consist of low undulating ridges of laterite, intersected by swamps or paddy land, contain *Palaquium canaliculatum*, a species which does not occur in the larger forests further inland. It attains a moderate size and is locally popular for constructional work : the proportion of sapwood of inferior strength and appearance is relatively high. No seedlings have been observed, but 50 or more saplings per acre have been reserved in fuel fellings in coppice areas in Polhunnawa Proposed Reserve : it has also been observed in Imaduwa, Dikkele, Yakkatuwa and Miriswatta. The latter forest is low lying and swampy and *Palaquium canaliculatum* and *Palaquium grande* (a water-loving species) are both common in the form of saplings, but it is so long since timber of either has been available that the local villagers refuse to recognise them as anything but jungle weeds. It is characteristic of *Palaquium grande* to flower and fruit in early youth. *Palaquium grande* var. *parvifolium* has only been located in Puhulhena forest at Haliela near Akuressa : its timber is entirely distinct from that of *Palaquium grande* from which further research may show it to be separable as a species.

These coastal forests are devoted to the production of firewood and common timber to meet urgent local needs and the specimens of *Palaquium* which they contain are only of incidental interest.

(*b*) The three species of economic importance, *Palaquium rubiginosum* (Tawenna), *Palaquium petiolare* (Kirihembiliya) and *Palaquium Thwaitesii* (Ratatiya) occur and can chiefly be propagated, in the larger forest blocks further inland such as Beraliya, Kanneliya and Sinha Rajah, like the subsidiary species *Palaquium laevifolium* and *Palaquium grande*, they are never dominant in secondary forest though, significantly enough, seedlings of *Palaquium petiolare* and *Palaquium rubiginosum* are found to be invasive into secondary jungle if the soil conditions are favourable. *Palaquium petiolare* is being tested in Chena reafforestation with manioc. Being probably as sensitive to fire and abuse as the Dipterocarps they disappear when the forest is subjected to heavy felling on license with the collection of sticks and poles and the burning of fernland for village grazing. *Palaquium* forests are comparatively remote and are characterised by a lofty canopy of the crowns of trees and one or more lower layers of shrubs and ferns : in Beraliya the soil is deep, fertile and completely protected against erosion and consists of laterite more or less denuded to expose the underlying boulders of gneiss : the altitude varies

TABLE II

Table showing Distribution of Species of Palaquium in the Galle District

Species.	*Forests and Altitude.*							*Coastal Forests.*				
	Beraliya 100-500 ft.	*Kanneliya 100-1600 ft.*	*Weeragam-kanda 100-500 ft.*	*Kottawa 200-500 ft.*	*Hinidum-kanda 200-1600 ft.*	*Puhulhena 100-300 ft.*	*Haliela (E.D.S.) 100-400 ft.*	*Miriswatta 100 ft.*	*Yakkatuwa 100 ft.*	*Polhun-nawa 100 ft.*	*Dikkele 100-300 ft.*	*Imaduwa 100-500 ft.*	*Kombala*
P. petiolare	×	×	×	×	×	×	×	—	—	—	—	—	×
P. grande	×	×	×	×	—	×	—	×	—	—	—	—	—
P. parvifolium	—	—	—	—	—	—	×	—	—	—	—	—	—
P. rubiginosum	×	×	×	×	×	—	—	—	—	—	—	—	—
P. canaliculatum	—	—	—	—	—	—	—	×	×	×	×	×	—
P. Thwaitesii	×	×	×	×	—	—	—	—	—	—	—	—	×
P. laevifolium	—	×	×	—	—	—	—	—	—	—	—	—	—
P. pauciflorum	—	×	—	—	—	—	—	—	—	—	—	—	—
I. lanceolata	×	—	—	—	—	—	—	—	×	×	×	—	—

x = collected or observed.

abruptly from 100 ft. to 600 ft. and the rainfall is estimated at 130 ins. Of a total area in Beraliya of 13,000 acres not more than 2,000 are estimated to be stocked with *Palaquium* : the forest is intersected with large tracts of fern which is annually burnt, and thus encroaches on the forest, and there are many hundred acres of forest cleared years ago for chena and which have only been reoccupied by secondary forest of inferior species : the lots which contain mature timber or regeneration of *Palaquium* are usually on the higher ridges and slopes and are potentially very productive.

A world shortage of timber has been predicted with confidence within the next 25 years and in Ceylon it will probably first result in the interruption of imported supplies of tea boxes. Of the Rs. 8,500,000 expended in 1926–27 on imported timber no less than Rs. 4,800,000 was spent on ceiling boards and teabox woods. Similarly the future supply of Teak from Siam is estimated on good authority to be very insecure, and any homegrown contribution to the total quantity of softwoods and hardwoods required locally will be valuable.

Palaquium petiolare is a very promising substitute for the imported Momi (*Abies firma* S. & Z.), and was used extensively for teaboxes in 1920, while *Palaquium rubiginosum* (Tawenna), recognised as a fair hardwood and *Palaquium Thwaitesii*, an average constructional timber, are readily saleable if marketed in large or small quantities in Beraliya and elsewhere.

These valuable species appear capable of affording a substantial contribution to any supply of homegrown timber. Advance growth is already plentiful over wide areas of the forests enumerated in the table VI, and there is evidence that such natural seedlings and saplings can be encouraged to the extent of restocking the area with 50 or more mature representatives of the genus instead of 4 as at present. On an experimental area of 55 acres in which the undergrowth was cut out to free seedlings and saplings of *Palaquium*, the results up to date are promising, although for various reasons the earlier fellings are considered too drastic. *Palaquium petiolare* appears to be sensitive to increased light in the seedling stage, but this and the other two species all respond well to increased light when they are once established and appear to be immune from damage by game : all are capable of enduring a considerable degree of shade, which in view of the partial suppression they will experience at some stage in the rotation is a favourable characteristic. The advance growth rarely shows any sign of the deformity usually caused by suppression.

Isonandra lanceolata is likely to prove intolerant of any degree of shade and can only be expected to appear in the form of seedlings when

the canopy has been finally opened out. *Palaquium laevifolium* is probably tolerant but appears to be very rare.

A further asset in this type of forest is the heavy yield of timber of common species which will be removed at a profit, to allow complete freedom of growth to the young *Palaquium*. To justify the treatment of new areas of *Palaquium* and the extension of the present rough cart tracks, a strip enumeration was commenced which indicates, up to date, an average yield of 2,848 cubic feet per acre of common timber and 393 cubic feet of *Palaquium* timber in two blocks 700 acres in extent. It also indicates a stocking of *Palaquium* seedlings and saplings of 2,000 per acre, and while this cannot be regarded as an average it suggests that the initial restocking of part of the area should present no difficulty. It is proposed that the initial treatment should precede the removal of large timber by about five years.

DESCRIPTION OF PALAQUIUM TIMBERS[1]

Kirihembiliya (*Palaquium petiolare*). *Weight*, very light and soft, porous; sometimes available in dimensions up to 12′ in girth. *Colour* of sapwood pinkish white ; heartwood salmon pink, lustrous, streaked with faint brown colouring, variable. *Vessels* large, irregularly plugged for part of their length, singly or radially in chains up to 6 in number : arrangement in echelon is common. *Rays* extremely fine, numerous and regular. *Concentric rings* very fine and faint, white.

Already a well-known tea box wood: suitable for ceiling boards, etc., when freshly cut is sufficiently dark to resemble *Tawenna*, for which it is sometimes substituted. It sometimes shows a very fine flowered effect in radial section, in the form of parallel bands of darker colour. Latex exudes freely from the bark and from the petiole of the leaf of seedlings and saplings.

Kiripedda (*Palaquium grande*). *Weight*, fairly heavy and hard. *Colour* of sapwood salmon pink, clearly defined from the purplish grey heartwood. *Vessels* numerous, of 2 sizes, moderately or extremely fine, not plugged, arranged singly or in pairs, threes, fours or sixes in radial chains forming groups with vessels in other rays. A feature of the radial chains is the rectangular form of the septa. Lustrous in radial section. *Rays* extremely fine, very numerous, exactly regular and equidistant. *Concentric rings* extremely fine, very numerous, almost regular, white,

1. Mature timber of *Palaquium grande* var *angustatum* and *Palaquium pauciflorum* has not yet been collected and classified.

fairly conspicuous in the timber of young trees. Latex is copious in bark and in the petiole.

All the saplings and the single large tree which have been felled up to date have hollows, probably due to suppression in early youth.

Hin-Molpedda (*Palaquium grande* var *parvifolium*). *Colour*, sapwood yellowish or pinkish white, merging into dull purplish, or reddish brown heartwood. *Vessels* not numerous, rather small, often singly or in short radial chains. *Rays* invisible under magnification of 5 diameters. *Concentric rings* only visible in sapwood, extremely fine and regular.

A wood of general utility which does not resemble *Palaquium grande* in any respect.

Tawenna (*Palaquium rubiginosum*). *Weight*, 58 lbs. per cubic foot, heavy, hard, durable. Sapwood narrow, pinkish white, merging into dark red heartwood. *Vessels* fairly large, numerous, appear to be sometimes plugged, singly or in radial chains up to 6 in number. *Rays* indistinguishable under low power. *Concentric rings* very fine, regular, numerous ; lighter in colour, very indistinct. Latex is copious in the bark of the mature tree ; also in the petiole of the young leaf.

A well-known timber greatly valued for constructional work and, to some extent, for furniture : it sometimes shows a fine flower in a radial section. It has a tendency to split.

Ela-Kirihembiliya (*Palaquium canaliculatum*). *Weight*, fairly heavy, moderately hard, observed up to 6′ in girth. *Colour* of sapwood pinkish or yellowish white, merging into heartwood, which is cloudy and darker than the sapwood, purple or greyish brown. *Vessels* fairly small, not straight longitudinally, partially plugged, very numerous, irregular in size, seldom singly, usually in chains of 2, 3 or up to 6 in number. Arrangement in echelon is common. *Rays* fairly fine and indistinct, white, sometimes deflected when passing a vessel. Invisible in heartwood. *Concentric rings* numerous, fairly conspicuous, regular, yellowish white, undulating in sapwood, very fine in heartwood. Watery latex occurs in the petiole of the young leaf. Latex is variable in the bark of the mature stem.

Occurs in the low undulating " kabook " forest, not in the main blocks of steep forest further inland. Over a limited area the timber is in good repute for building purposes.

Ratatiya (*Palaquium Thwaitesii*). *Weight*, fairly heavy ; softer than *Palaquium rubiginosum*. *Colour*, variable dull bluish or brownish purple with shades of yellow and green : lustre is conspicuous in radial section. Heartwood purplish brown. *Vessels* smaller than *Palaquium rubiginosum*,

usually in radial chains which sometimes exceed 10 in number, vessels variable in size, often connected diagonally. *Rays* invisible under a hand lens. *Concentric rings* extremely fine, regular, equidistant, inconspicuous, sometimes only visible when moist. A useful timber, but a poor substitute for *Tawenna* (*Palaquium rubiginosum*), for which it is sometimes mistaken.

Et-Molpedda (*Palaquium laevifolium*). *Weight*, very heavy, very hard. *Colour*, sapwood yellowish pink, deepening to bright pinkish brown, clearly distinguished from dark brown heartwood. *Vessels* very small, usually plugged with white callus, not numerous, arranged singly or in radial chains which appear not to exceed 4 in number ; arrangement in echelon is rare. The white, apparently crystalline, substance in vessels serves to distinguish it from *Isonandra*. *Rays* hardly distinguishable under low power ; very fine, faint, white. *Concentric rings* very fine but distinct, numerous, yellowish white, undulating, not equidistant, their arrangement in zones suggests the influence of seasons.

Apparently a wood of exceptional strength for constructional work: also suitable for furniture.

Molpedda (*Isonandra lanceolata*). *Weight*, heavy, hard. *Colour* of sapwood pinkish brown, clearly defined from dark brown heartwood, which appears to be a more regular cylinder than in *Palaquium laevifolium*. *Rays* not distinguishable under low power. *Concentric rings* very fine, indistinct. A watery latex occurs in the petiole of the young leaf.

Examination of these timbers under the low power of a microscope shows that the alternating bands of the light and dark tissue are possibly due to the deposition of modified latex. These bands may be found to correspond with periods of "wintering" or shedding of leaves in the dry season, a phenomenon which is familiar in *Hevea*. The second general characteristic of all the timbers is the distribution of vessels in radial chains: this must be closely connected with a tendency to radial splitting and is most marked in *Palaquium canaliculatum* and least in *Palaquium petiolare*. The timber of the latter is found to be composed of thin-walled tissue of great uniformity and, probably, of very rapid growth : the vessels though large are evenly distributed and the wood, though not durable when exposed in the open, is likely to be readily saleable as at present in the largest quantities the Forest Department can ever supply.

BOTANICAL KEY TO THE SPECIES

1. Tertiary veins of the leaves indistinct; flowers stalked:
   2. Leaves of mature trees elliptic–lanceolate; leaves of young plants linear-lanceolate ..... *P. Thwaitesii*
   2.* Leaves of mature trees obovate, often reddish–pubescent beneath; leaves of young plants elliptic–lanceolate; fruit obovoid, purplish ..... *P. rubiginosum*

1.* Tertiary veins of the leaves distinct:
   3. Tertiary veins of the leaves subparallel:
      4. Leaves bright green beneath; flowers sessile or shortly stalked; fruits fusiform.
         5. Leaves always narrowly oblanceolate; flowers shortly stalked; fruit yellow ..... *P. laevifolium*
         5*. Leaves very variable; flowers not stalked; fruit red ..... *Isonandra*
      4.* Leaves silvery beneath; flowers on long stalks; fruits oblong; leaves of mature trees broadly elliptic, of young plants, broadly oblong ..... *P. petiolare*
   3.* Tertiary veins of the leaves reticulate:
      6. Leaves of mature trees obovate–lanceolate, silvery beneath; of young plants, elliptic–lanceolate; flowers stalked; fruits obovoid or subglobose ..... *P. grande*
      6.* Leaves oblong or oblong–lanceolate:
         7. Flowers stalked; fruit obovoid; leaves silvery beneath ..... *P.canaliculatum*
         7.* Flowers not stalked; fruit fusiform; leaves bright green beneath ..... *P. pauciflorum*

The Sapotaceae, Apocynaceae, certain Urticaceae (*Ficus*, *Antiaris*, *Artocarpus*, *Phyllochlamys*, *Streblus*, and *Allaeanthus*), and some species of *Euphorbia* are, as far as is known, the only arborescent laticiferous plants found wild in Ceylon. The Euphorbias are leafless cactus–like plants, not likely to be confused with anything else. The Apocynaceae, except *Cerbera*, have either opposite or whorled leaves, while the Urticaceae can usually be distinguished from the Sapotaceae by the large deciduous stipules.

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3. Wright, H. Report of the Scientific Assistant, p. 6. Ceylon Administration Reports, 1901.

4. Anon. Gutta Percha of *Palaquium petiolare* from Ceylon. Bull. Imperial Instit. I, pp. 118–119 (1903).

EXPLANATION OF PLATES

Plate XXXIX

Fig. 1. Transverse section of wood of *Palaquium petiolare* × 40.
Fig. 2. ,, ,, ,, *P. rubiginosum* × 40.
Fig. 3. ,, ,, ,, *P. Thwaitesii* × 40.
Fig. 4. ,, ,, ,, *P. canaliculatum* × 40.

Plate XL

Fig. 1. Transverse section of wood of *P. grande* × 40.
Fig. 2. ,, ,, sapwood of *P. grande* var. *parvifolium* × 40.
Fig. 3. ,, ,, heartwood of *P. grande* var. *parvifolium* × 40.
Fig. 4. ,, ,, wood of *P. laevifolium* × 40.

Plate XLI

Fig. 1. Transverse section of wood of *Isonandra lanceolata* × 40.
Fig. 2. Tangential section of sapwood of *Palaquium grande* var. *parvifolium* × 40
Fig. 3. Sapling of *P. rubiginosum*
Fig. 4. Sapling of *P. petiolare*.

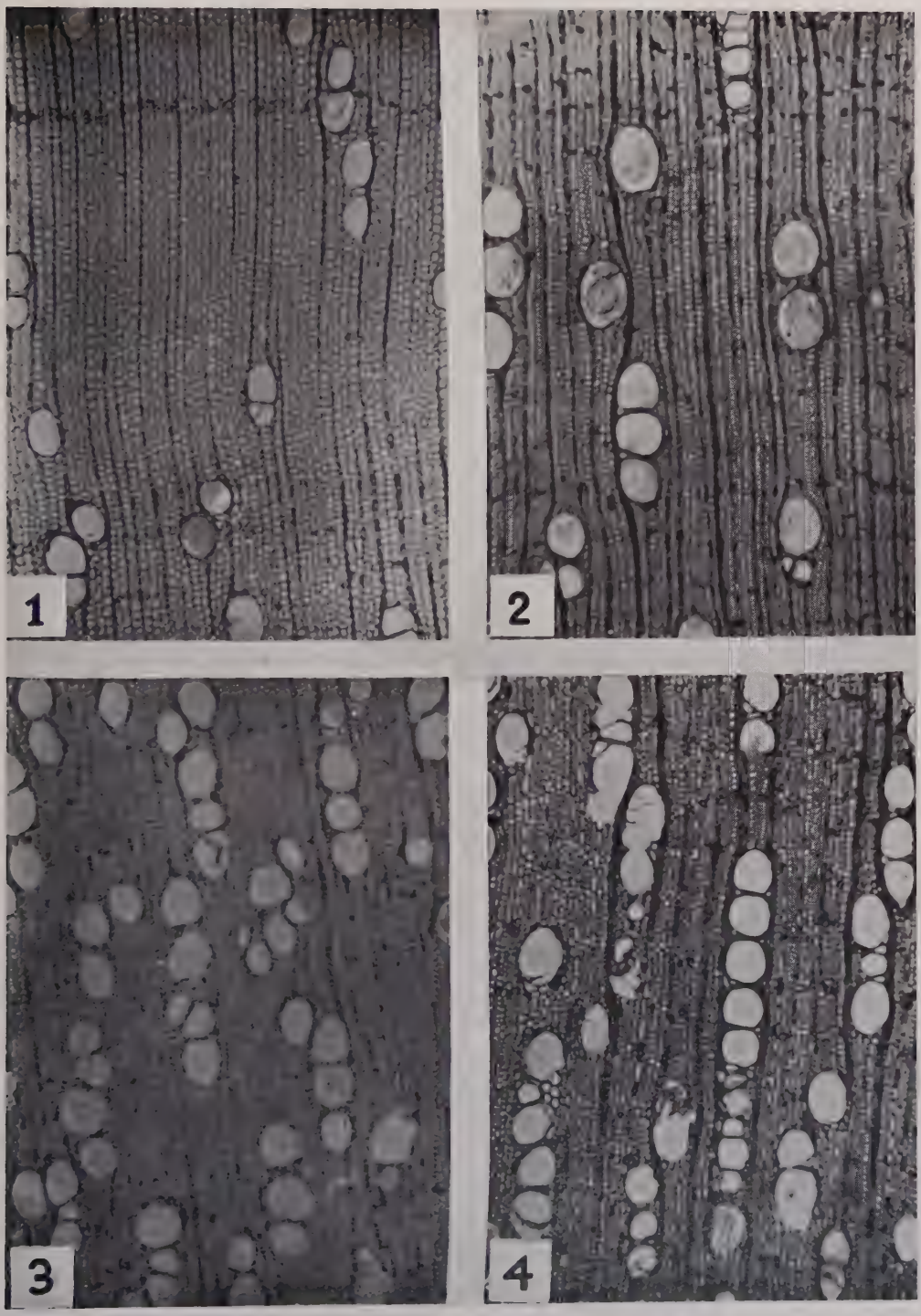

Photo. by S. D. J. E. Senaratna.

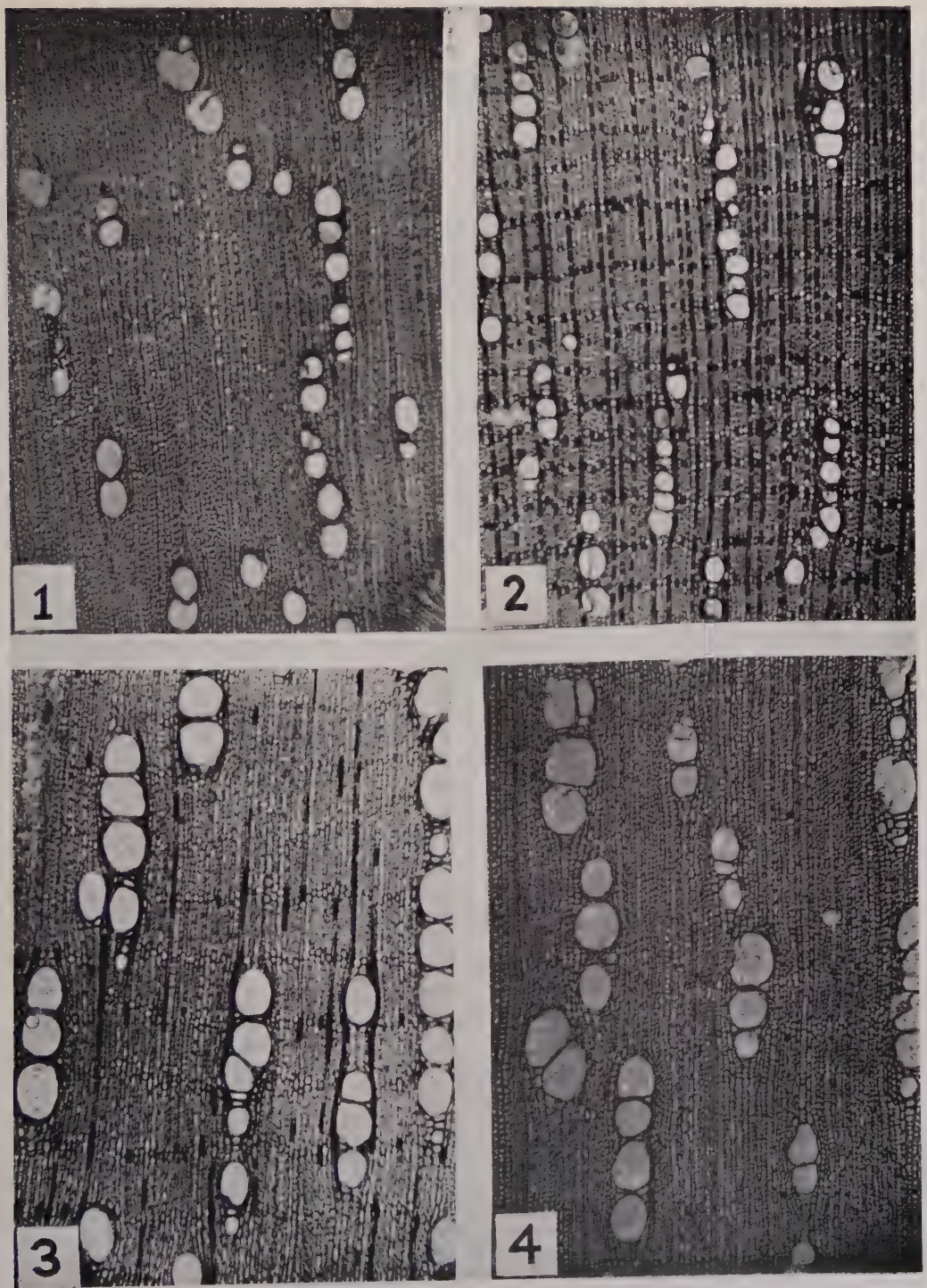

Photo by S. D. J. E. Senaratna.

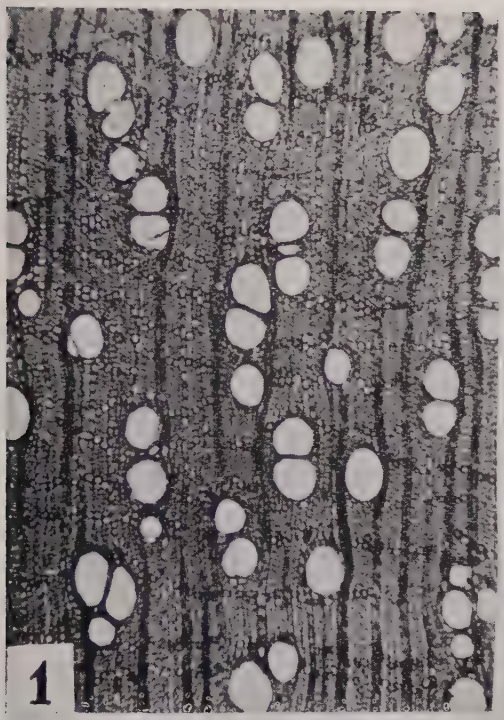

Photo. 1 & 2 by S. D. J. E. Senaratna.

Short Notes

Roxburgh's Hortus Bengalensis

Robinson[1] when discussing the species published in Roxburgh's Hortus Bengalensis makes no reference to the work entitled "A Catalogue of Plants described by Dr. Roxburgh in his MSS. Flora Indica, but not yet introduced into the Botanical Garden" which appears to have been edited by Carey and is usually bound up with the Hortus Bengalensis. Though dated 1813, internal evidence (the note at the bottom of p. 83) shows that it was compiled later than the Hortus Bengalensis. The few pages that are numbered continue the numbers of the Hortus Bengalensis, hence this Catalogue is cited in the Index Kewensis as "Roxb. Hort. Beng." with the numbers of the pages in square brackets.

The following species are published :—

Eranthemum montanum Roxb. l. c. p. [80], based on *Justicia montana* Cor. Pl.=DAEDALACANTHUS FASTIGIATUS (Lamk.) *Justicia fastigiata* Lamk. 111. 1, p. 41 (1791). *Daedalacanthus montanus* T. And. in Thw. Enum. p. 229 (1864).

Salvia lanata Roxb. l. c. p. [80] nec. Salisb. (1796) nec. Stokes (1812), based on *S. integrifolia* [Hardwicke in] A. Res. (1799) non Ruiz. and Pav. (1798).

The validity of this name depends on the status of *S. lanata* Salisb., which is reduced to *S. canariensis* Linn. in the Index Kewensis, and *S. lanata* Stokes, which is reduced to *S. aethiopica* (probably a misprint for *S. Aethiopis* Linn.). *S. integrifolia* R. & P. appears to be a valid species.

Piper arborescens Roxb. l. c. p. [80] non Auct., based on H.A. 5. t. 28. f. 1=THOTTEA DEPENDENS Klotzsch, in Monatsb. Acad. Berl. 1859, p. 589.

Achyranthes nodiflora Roxb. l. c. p. [84], based on *Celosia nodiflora* Cat.=ALLMANIA sp.

The abbreviation "Cat." refers to the Hortus Bengalensis, p. 19; as no authority is given on p. 19 I do not think that the publication can be considered valid. *Celosia nodiflora* Linn., which is probably meant is *Allamania nodiflora* R.Br. This combination received valid publication in the Flora Indica 1, p. 678.

1. Robinson, C.B.—Roxburgh's Hortus Bengalensis. Philippine Journal of Science, Botany, VII., pp. 411–419, Manila (1912).

Alyxia stellata Roxb. l.c. p. [84], based on *Gynopogon stellatum* Cat. =A. STELLATA R. and S. Syst. IV., p. 439 (1817–30). " Cat." refers to p. 19 where H.A. 5. t. 20 is cited. Roxburgh is hence the authority for *Alyxia stellata*.

Amyris Commiphora Roxb. l. c. p. [88], based on *A. Agallocha* Cat. [p. 28, nomen]=COMMIPHORA ROXBURGHII (Arn.) *Balsamodendron Roxburghii* Arn. in Ann. Mag. Nat. Hist. III, p. 86 (1839). *Commiphora Agallocha* Engl. in DC. Mon. Phan. IV, p. II (1883). *Amyris serratifolia* Rottl. nomen.

Not published till 1824, in the Flora Indica.

A. suffruticosa Roxb. l.c. p. 88, based on *A. fruticosa* Cat. [p. 28, nomen].=CLAUSENA SUFFRUTICOSA W. & A. Prodr. p. 96, (1834).

Not published till 1824 in the Flora Indica.—A. H. G. Alston.

(Received for publication 3rd April, 1929)

Inverted flowers in the Leguminosae

Piper and Dunn.[1] describe the flowers of *Canavalia* (*C. virosa* W. and A. ?) as sternotribal, but quote Mr. I. H. Burkill as recording that those of *C. maritima* Thouars (*C. rosea* DC.) as dorsotribal.

All the specimens I have seen of *C. virosa* W. and A. *C. gladiata* DC. and *C. ensiformis* DC. have had inverted flowers. *Clitoria Ternatea* Linn., *C. laurifolia* Poir. (*C. cajanifolia* Benth.) *Centrosema pubescens* Benth., and *C. Plumieri* Benth. have also inverted flowers.

With the exception of *Canavalia virosa* and *Clitoria laurifolia*, all these species fruit freely at Peradeniya.

Centrosema pubescens Benth. is incorrectly figured with an erect standard in the Flora of Jamaica (IV, 2, p. 45).

The inverted flowers were mentioned in the original generic description of *Centrosema*—A. H. G. Alston.

1. C. V. Piper and S. T. Dunn–A Revision of Canavalia. Kew Bull. 1922, pp. 129–145.

(Received for publication 17th April, 1929).

Some Abnormalities of the Coconut Palm

BY

S. D. J. E. Senaratna

Acting Systematic Botanist, Department of Agriculture, Ceylon

WITH TWO PLATES

I. Fruit Germinating to Produce Three Plants

In the nursery of Mr. L. W. Perera's coconut estate at Horombawa, Kurunegala District, one fruit was found to have given rise on germination to three plants instead of the usual one. This was planted for its greater safety near a watchman's hut. As the plants increased in size they bent outwards diverging from one another. One of the plants, the central one in the photograph, is a little smaller than the other two which are of nearly the same size. In April, 1928, when this photograph was taken, the smaller plant had eight leaves while the other two had nine each. The plants are now about four years old.

In the *Mahawansa*, Chapter LXXXVI, verses 4 and 5 the chronicler has "Then the King (Parakramabahu II., 1240–1275 A.D.) was musing "My minister Devapratiraja now lives fully enlightened in the Faith, for having prayed earnestly that he might attain buddhahood, when he planted a coconut, (for a sign to be given him), from its three eyes, three plants arose."

Quisumbing[1] records another case from Manila.

As is generally known the coconut has a trilocular fruit in which usually only one loculus is developed due to the formation of only one embryo. Occasionally a bilocular fruit is met with and very rarely a trilocular one. The specimen I have described is an example of the latter condition. Here the three embryos have developed into plants.

II. Abnormal Inflorescence

Petch (in this Journal, Vol. VI., pp 27–29 (1915), describes some abnormal inflorescences obtained from Chilaw. Ridley[2] records another instance of this from Lumut, in the Dindings. I have observed a similar case at Mutugala, Kurunegala District, and shall briefly describe it.

The inflorescence is from a tree which, except for this divergence, appears to be quite normal. The tree is about 50 feet high and stands 6 feet away from a paddy-field area. The origin of the inflorescence is, as in other cases, in the axil of a leaf—one for each leaf.

The spathe bursts to expose an axis bearing leaf-like organs. These are modified bracts. The examination of a specimen in which the spathe had burst a few days before gave the following results.

The axis was cylindrical, $4\frac{1}{2}$ inches long and 2 inches in diameter and bore 9 bracts. The bracts were much expanded at the base and attached completely round the axis. Distally the bracts narrowed down to a spathe–like structure and ended in a leafy tip. An analysis of this inflorescence gave

Bract.	*Breadth of Base.*	*Length Leafletless.*	*Leaflet–bearing.*
1.	7 inches	3 inches	5 inches
2.	$6\frac{1}{2}$,,	12 ,,	5 ,,
3.	$5\frac{1}{2}$,,	12 ,,	6 ,,
4.	$4\frac{1}{2}$,,	9 ,,	12 ,,
5.	$3\frac{1}{2}$,,	$6\frac{1}{2}$,,	15 ,,
6.	$3\frac{1}{4}$,,	4 ,,	8 ,,
7.	$2\frac{1}{2}$,,	3 ,,	17 ,,
8.	2 ,,	— ,,	9 ,,
9.	$1\frac{1}{2}$,,	— ,,	8 ,,

Bract 6 had a leafy tip which was much compressed, as evident in the zig–zig form of the leaflets.

8 and 9 were unexpanded. The axils of the bracts were bare in all cases.

The examination of an older inflorescence which had fallen off the tree gave the following results. The axis was elliptic (with axes $2\frac{1}{2}''$ and $1''$) at the base for nearly 6 inches when it merged into a circular form ($2''$ diameter) for 3 inches. Many of the older bracts had fallen off as evinced by the scars on the axis.

An analysis of the bracts left on it showed,

Bract.	*Breadth of Base.*	*Length Leafletless.*	*Leaflet–bearing*
1.	8 inches	28 inches	12 inches
2.	7 ,,	24 ,,	13 ,,
3.	$5\frac{1}{2}$,,	21 ,,	13 ,,
4.	5 ,,	19 ,,	12 ,,
5.	$4\frac{1}{2}$,,	18 ,,	$7\frac{1}{2}$,,
6.	$4\frac{1}{2}$,,	16 ,,	19 ,,
7.	4 ,,	14 ,,	18 ,,
8.	$3\frac{3}{4}$,,	13 ,,	17 ,,

As Petch (*loc. cit*) observes, in this case also, the production of these large bracts is attended by the complete absence of the flowering branches.

III. Leaf with Branched Rachis

This occurred in a three-year old plant growing near the writer's home at Amandoluwa, in the Negombo District. There was nothing unusual in the plant for about two and a half years. Then a leaf was produced which had the leaflets irregularly distributed on the rachis. Some of the leaflets persisted in the young attached condition in groups of three to five and did not separate from one another even in the fully developed leaf. Between these groups on either side of the rachis were spaces devoid of leaflets. The bare area and the leaf-groups of one side did not correspond with those of the other but alternated irregularly with them, while scattered in among them were the ordinary leaflets.

The next leaf was unique in that the rachis gave off secondary axes bearing leaflets. About two-thirds of the way down its length, six feet away from its origin, the primary rachis gave off a smaller secondary axis about 18 inches long and bearing leaflets. This resembled the apical end of the ordinary leaf. 18 inches further another secondary axis branched off from the primary axis while still beyond a third and a fourth were formed before the primary axis itself terminated. The second, third and fourth were small, bearing only the leaf-groups as at the leaftip of the young plant.

The later formed leaves were of the ordinary type. As far as I am aware a similar case has not been recorded before.

This case is particularly interesting in view of the " Phyllode Theory " of the Monocot leaf advocated by Arber,[3] for according to this theory the Monocot leaf is a phyllode corresponding to the leaf-stalk of the Dicot, the true lamina of which is unrepresented in the Monocot and the leaflets are but expanded infoldings of the stalk. Hence this would appear to be a proliferating phyllode.

The photograph was taken on the 6th of February, 1926.

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2. Ridley, H. N.—Branching in Palms. *Ann. Bot. XXI, 1907, pp. 420-1 pl. XXXVII, XXXVIII.*
3. Arber, A.—Monocotyledons. *Camb. Univ. Press, 1925.*

EXPLANATION OF PLATES

Plate XLII, Fig. 1. Three plants from one fruit.
,, 2. Abnormal inflorescence. The one on the left of the figure shows the unopened condition, that on the right a later stage, while in the centre is one that had fallen off.
Plate XLIII, ,, 3. Plant bearing two abnormal leaves.
,, 4. Leaf with branched rachis.

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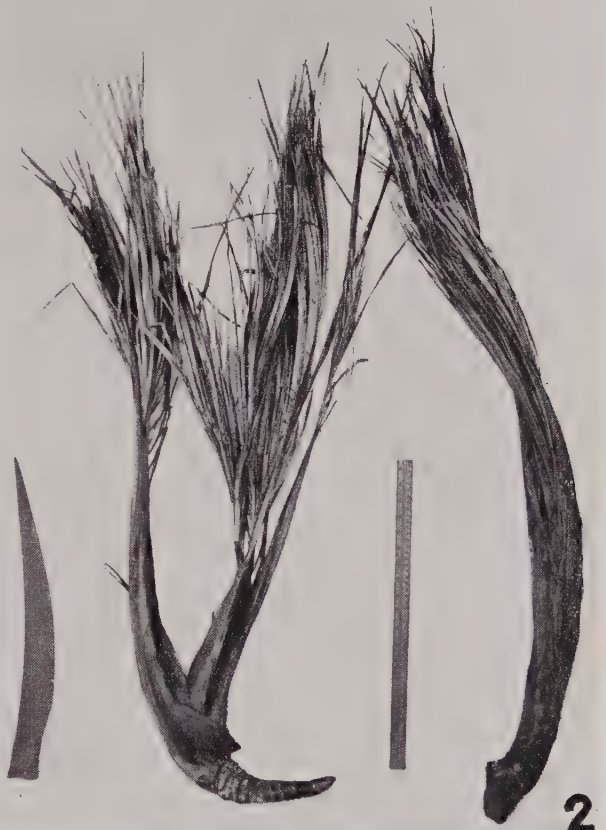


Photo. by S. D. J. E. Senaratna.

1. Three Plants from One Fruit.
2. Leafy Inflorescence.

Photo. by S. D. J. E. Senaratna.

3. Plant Showing Two Leaves of Unusual Form.
4. Branched Leaf.

An Abnormal Rose

BY

S. D. J. E. Senaratna

Acting Systematic Botanist, Department of Agriculture, Ceylon

WITH ONE PLATE

The rose now to be described was produced on a plant in Mr. J. C. Drieberg's garden at Peradeniya. All the other flowers on the plant were normal.

The five sepals were transformed into 5 foliage leaves arranged in a whorl round the axis. Just above these and alternating with three of them were three of the white petals, while the fourth petal was raised up 3 millimetres and the fifth 8 millimetres along the axis. Two centimetres from the point of origin of the calyx, 5 white petal-like structures arose in a whorl and in the axil of each of these was a bud. A centimetre above this the axis gave off leaves again and continued as a vegetative bud.

This flower is rather interesting as it shows in one specimen, phyllody of the calyx, longitudinal displacement with reduction in number of the corolla segments, petalody of the androecium, metamorphosis of the gynoecium (buds), and median vegetative proliferation of the thalamus.

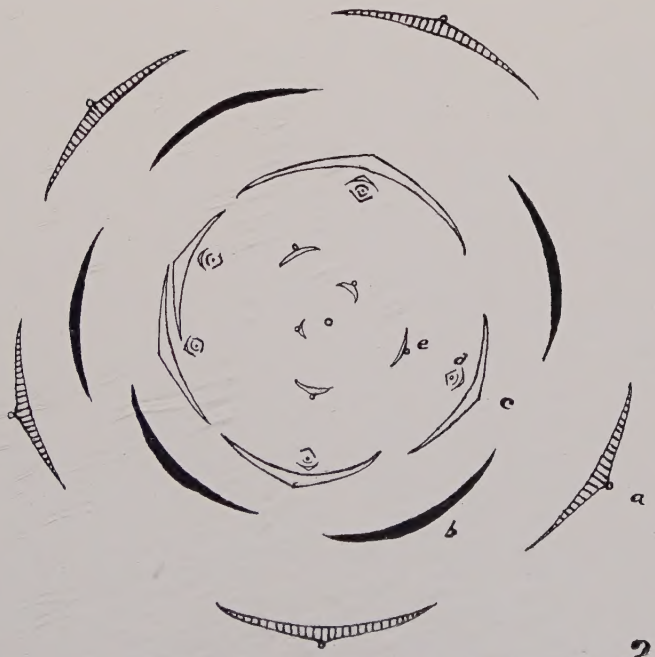
Plate XLIV shows a drawing and a floral diagram of the specimen. The specimen was received on the 10th November, 1928.

EXPLANATION OF PLATE XLIV.

1. Abnormal rose, natural size.
2. Floral diagram of abnormal rose—
   - a. Leaf in place of sepal.
   - b. petal.
   - c. petal-like structure of inner whorl.
   - d. bud in axil of c.
   - e. leaf on prolonged axis.

(Received for publication 13th September, 1929.)

1



2

S. D. J. E. Senaratna, del.

1. Abnormal Rose, (natural size)
2. Diagram of Same

EDITORIAL NOTE

All communications with regard to exchanges or any matter arising out of the present publication should be addressed to

The Director of Agriculture,
Peradeniya, Ceylon

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